Part

D

Section 5: Incremental Benefit Analysis of Aquatic HCP Proposals Made by PALCO and NMFS

METHODS USED TO DEVELOP TABLE 1 and 2

Economic Analysis: Columns 2-6 of Table 1 and 2 outline the approach used to determine the economic costs of each proposed mitigation. For each mitigation, either the width of stream buffer, or the miles of roads affected by the proposal are identified. For mitigations affecting stream buffers, miles of stream by stream class was used to calculate the number of acres of land subject to the proposed mitigation (for roads the number of miles is tracked). Using the results of PL's sustained yield model, the impact of each mitigation on the long term sustained yield (LTSY) of forest products was determined (excluding road mitigations). This information is presented in Table 1 and 2 in two ways, as the total reduction in LTSY for each mitigation, and the reduction in LTSY per acre of land impacted by the proposal. Annual costs were then developed using the assumptions in the 'Financial Factors" box at the base of Table 1. These annual costs were then discounted over a 100 year period and reported as the total impact on PL's present net worth.

Large Woody Debris Analysis: Columns 7 and 8 address the benefits and costs, respectively, of each of the proposed mitigations on large woody debris recruitment to streams. Values listed as benefits were derived as follows:

- R2 Resource Consultants estimated the number of LWD pieces per 100 ft. of stream that would result if each mitigation were implemented. Methods used to develop these estimates are described in the attached report *Incremental Benefit Analysis of Aquatic HCP Proposals.*

- The number of LWD pieces expected from each mitigation was divided by the selected baseline, in this case LWD recruitment expected under unmanaged conditions, and multiplied times 100 percent, The baseline represents an estimate of conditions associated with streams that are fully functional. Fully functional, as used here, follows NMFS' convention, meaning a system that fully provides the resources and conditions required by aquatic plant and animal species in general, and by coho salmon in particular. Thus, dividing the incremental increase in LWD expected under each mitigation by the baseline, in effect, provides an estimate of the percent of full function, or functionality, provided by each proposal.

- One complication is that the mitigations explicitly address Class I and Class II streams separately. Thus, in R2's analysis, benefits for the mitigations are estimated independently for Class I and Class II streams. Yet some process for combining the benefits to Class I and Class II streams is needed because functionality involves an entire stream system. For example, a set of proposals that collectively provide high benefit for sediment control along Class I streams could still be insufficient to protect fish if they allow large sediment inputs to Class II streams (i.e., because sediment in Class II streams will travel downstream to Class I reaches). Thus, "weighting factors" relating expected functionality to stream class were developed.

- For LWD the weighting factors were .75 for Class I streams and .25 for Class II streams (see the Relative Contribution to Stream Function box at the bottom of Figure 1). That is, each of the LWD benefits estimated by R2 were multiplied times either .75 or .25 to develop an overall assessment of the increase in functionality associated with each mitigation. These weighting factors were selected based on the following rationale: a) a large body of scientific literature indicates that LWD levels are one of the most important attributes of stream function for fish; b) only LWD in Class I streams provides habitat and cover to fish, so all of the functional benefit noted in a) is limited to the LWD in Class I streams, and c) LWD in Class II streams can help to retain and "meter out" sediment and leaf litter, thus LWD in these streams has a lessor, but still important role.

- So, values reported in Column 8 represent the incremental increase in stream function expected from each mitigation, These estimates derive from R2's report but include the "weighting factor" adjustment noted above.

Before the incremental cost of each mitigation could be determined, an additional weighting factor is needed. Because most mitigations have incremental benefit for all three areas analyzed in Table 1, LWD, sediment, and canopy/temperature, the total cost of each mitigation must be allocated among the various benefit types. The Relative Contribution of Mitigations to Function box at the bottom of Figure 1 outlines the cost weighting's used here. From this table, 15 percent of the costs of any width related mitigation, 55 percent of the cost of no cut zones, 50 percent of the cost from increases in stand density (other than no cut) and 0 percent of the costs for road mitigations were allocated to LWD. These allocations were developed by examining the amount of benefit produced by each category of mitigation to each of the three assessment areas (i.e., LWD, sediment and temperature/canopy). Values for this effort were taken from R2's Incremental Benefit report, and the calculated benefit values from Table 1.

Thus, values in Column 9 were determined by a) multiplying the value in the Impact on Present Net Worth column (Column 7) times the weighting for costs, and b) dividing the result by the value for the Percent Marginal Impact (Column 8).

Sediment Analysis: All methods used for sediment basically follow those for LWD. For this variable, R2 estimated the percent of all sediment from roads and management related inputs from stream banks that would be prevented from entering streams if each of the mitigations were implemented. The assumed baseline was 100 percent, that is, in a fully functioning watershed, 100 percent of the sediment from these sources would be prevented from entering streams.

Weighting factors for sediment benefits by stream class were .5 and .5 for Class I and Class II: streams, respectively. The rationale for this is that both Class I and Class II streams are important sources of sediment that affect aquatic plants and animals. Although there are more miles of Class II streams, potentially arguing for increased weighting for this class, only Class I streams contain fish, so sediment in these streams is arguably more important In addition, most of the streams on PL's property that are subject to channel "migration" are Class Is, making these channels more important in the analysis of sediment from banks and adjacent slopes.

Weighting factors for cost allocation were: 30 percent of the costs of any width related mitigation, 5 percent of the cost of no cut zones, 5 percent of the cost from increases in stand density (other than no cut) and 95 percent of the costs for road mitigations. These weightings were again determined by examining the amount of benefit produced by each category of mitigation to each of the three assessment areas (i.e.,LWD, sediment and temperature/canopy).

Temperature/Canopy Analysis: All methods used for temperature/canopy follow those for LWD. For this variable, R2 estimated the canopy density or canopy closure that would result if each of the mitigations were implemented. The assumed baseline was 92 percent. This was based on a statistical analysis in R2's report that showed an average canopy closure in unmanaged forests of 92 percent (although values in unmanaged forests are quite variable),

Weighting factors for canopy benefits by stream class were .6 and .4 for Class I and Class II streams, respectively. The rationale for this is: 'a) many Class II streams have reduced or no flow during the warmest part of the summer, and therefore have little effect on temperatures in larger streams; 2) even if Class II streams deliver cooler water to Class I segments, poor canopy cover along Class Is can (and does) result in unacceptably high temperatures in fish bearing waters. This rationale does not conclude that Class II streams are unimportant in determining temperatures, only that they are somewhat less important than conditions in Class I streams.' Hence the 60/40 weighting.

Weighting factors for cost allocation were; 55 percent of the costs of any width related mitigation, 40 percent of the cost of no cut zones, 45 percent of the cost from increases in stand density (other than no cut) and 5 percent of the costs for road mitigations. These weightings were again determined by examining the amount of benefit produced by each category of mitigation to each of the three assessment areas, LWD, sediment and temperature/canopy. A 5 percent benefit to roads was assigned because of the potential for roads through riparian zones to result in locally high thermal loading rates. PL'S road mitigations will remove some roads from riparian zones, and result in vegetative regrowth along others.

ide by Side Incremental Benefit Analysis of Watercourse and Lake Protection Zone Mitigations - Table 1

10/15/97

Proposed Mitigation	Impacted WLPZ Width Foet	Impacted Acres On LTSY	Impact On LTSY Total	Impact On LTSY MBF/Acre	Cost per Impact Year	Cost per Impact Present Net Worth	Percent Marginal Impact LWD	Marginal Cost per Percent LWD	Percent Marginal Impact Sediment Delivery	Marginal Cost per Percent Sediment Delivery	Percent Marginal Impact Temp.	Marginal Cost per Percent Temp.	Percent Total Function	Marginal Cost per Percent Total Function
e 1973 as % of Fully Functi	al						6.2%		0.0%		30.0%		12.1%	
R over pre 1973														
a55 1 WLPZ 0 lo 100'	100	6,140	4.651	0.79	$3,152,890	$34,055,642	21.6%	$237.9021	14.3%	$714.4541	21.7%	$864,995		
ass 2 WLPZ 0 to 75'	75	13.028	10.292	0.79	$6,689,621	$72,257,309	4.2%	$2,553,262	11.9%	$1,829,299	9.8%	$4,061,869		
		19,168	15,142		$9,842,511	$106,312,951	25.7%	$1,377,821	26.2%	$1,355,033	31.4%	$1,127,111	27.8%	$3,828,545
over FPR							31.9%		26.2%		61.4%		39.8%	
ass 1 30' No Cut	30	1,842	1,901	1.032	$1,235,614	$13,346,363	30.3%	$242,021	1.3%	$513,322	6.2%	$861,334		
ass 1 WLPZ WHR6 30 lo 10(	70	4,298	860	0.2	$558,740	$6,035,177	2.5%	$1,226,662	0.3%	$1,207,035	0.9%	$2,977,883		
lass 1 WLPZ 100 to 170'	70	4,298	3,009	0.7	$1,955,590	$21,123,120	1.0%	$3,300,487	2.5%	$2,534,774	7.8%	$1,484,882		
lass 2 WLPZ WHR6 0 lo 75	75	13,020	2,606	0.2	$1,693,575	$18,292,990	4.9%	$1,877,167	0.8%	$1,219,533	3.3%	$2,458,735		
lass 2 WLPZ 75 to 100	25	4.343	3.040	0.7	$1,976,836	$21,341,821	0.4%	$8,770,811	0.2%	$32,012,732	3.0%	$3,912,687		
orm Proofing (50 miles/year))	50	Miles				$12,388,346			50.0%	$235,379				
		8,641	11,414		$7,419,358	$92,527,816	39.0%	$791,082	55.0%	$560,769	21.3%	$1,449,220	38.4%	$2,408,126
MFS Option 1 over PL							70.9%		81.2%		82.7%		78.2%	
lass 2 30' No Cut (40%)	30	2,004	2,151	1.032	$1,398,216	$15,102,692	3.5%	$2,400,717	0.1%	$15,102,692	1.2%	$4,967,891		
lass 2 WLPZ 100 lo 130'	30	5.211	3,648	0.7	$2,371,005	$25,610,165	0.1%	$42,683,642	1.3%	$6,146,444	3.7%	$3,766,204		
) Year WLPZ cutting Cycle		31,628	8,666	0.274	$5.632.947	$60,843,740	5.0%	$6,084,374	2.5%	$1,216,875	1.6%	$17,112,302		
lass 1 Slope Distance	13	798	559	0.7	$363.181	$3,922,865					0.0%			
lass 2 Slope Distance	10	1.737	1,216	0.7	$790,335	$8,536,728					0.8%	$5,988,776		
hannel Migration Zone		2,000	3,408	1.704	$2,215,200	$23,927,272	1.4%	$9,400,000	2.7%	$443,098	3.2%	$2,990,909		
torm Proofing (50 miles/year)	50	Miles				$8,741,024			10.0%	$830,397				
		9,746	19,648		$12,770,883	$146,884,508	10.0%	$4,913,562	18.5%	$2,963,027	10.5%	$4,636,515	12.3%	$11,898,554
MFS Option 2 over PL							81%		98%		93%		90.6%	
lass 2 30' No Cut (40%)	30	2.084	2.151	1.032	$1,398,216	$15,102,692	3.5%	$2,400,717	0.5%	$1,510,269	1.2%	$4,967,991		
la55 2 WLPZ 100 to 170' (50%	70	6,080	4,256	0.7	$2,766,173	$29,878,550	0.2%	$24,557,712	1.0%	$8,963,565	2.5%	$6,521,112		
) Year WLPZ cutting Cycle		34.562	9,475	0.274	$6,159,054	$66,526,439	5.0%	$6,652,644	2.5%	$1,330,529	1.6%	$18,710,561		
lass t Slope Distance	13	798	659	0.7	$363,161	$3,922,865					0.0%			
lass 2 Slope Distance	10	1.737	1,216	0.7	$790,335	$8,536,728					0.8%	$5,988,776		
hannel Migration Zone		2,000	3.400	1.704	$2,215,200	$23,927,272	1.4%	$9,400,000	2.7%	$443,098	3.2%	$2,990,909		
torm Proofing (50 miles/year)	50	Miles				$8,741,024			10.0%	$830,397				
		10,615	21,065		$13,692,158	$158,635,571	10.0%	$5,198,570	16.7%	$3,126,146	9.3%	$5,801,570	12.0%	$13,030,342
MFS Option 3 over PL							81%		98%		92%		90.3%	
lass 2 30' No Cut	30	5,211	5,378	1.032	$3,495,539	$37,756,730	8.6%	$2,412,571	1.3%	$1,610,269	3.0%	$4,961,463		
0 Year WLPZ cutting Cycle		22.944	6.287	0.274	$4,086,326	$44,138,067	5.0%	$4,413,807	2.7%	$811,362	1.1%	$18,056,482		
la55 1 Slope Distance	13	790	559	0.7	$363,161	$3,922,865					0.0%			
lass 2 Slope Distance	8	1,390	973	0.7	$632.266	$6,829,383					1.6%	$2,401,637		
hannel Migration Zone		2,000	3,408	1.704	$2,215,200	$23,927,272	1.4%	$9,400,000	2.9%	$408,315	3.2%	$2,890,909		
torm Proofing (50 miles/year)	50	Miles				$8,741,024			10.0%	$830,397				
		4,188	16,604		$10,792,514	$125,316,341	15.0%	$2,783,116	16.9%	$2,471,456	6.9%	$4,686,775	13.6%	$9,210,864
							80%		98%		92%		91.9%	

hysical Factors	Acres	MBF/Acre
:lass 1 acres per fool	61.4	
:lass 2 acres per fool	173.7	
latrix to Selection (150 BA)		0.79
VHR6 lo No Cul		1.032
latrix lo WHR6		0.7
latrix lo No Cut		1.704
0 year cutting cycle		0.274
hannel Migration Zone		2,000

Relative Contribution to Stream Function

	LWD	Sediment	Shade
Class 1	75%	50%	60%
Class 2	25%	50%	40%

Relative Contribution of mitigations to function

	Width	Zone No Cut	Prescription	Roads
LWD	15%	55%	50%	0%
Sediment	30%	5%	5%	95%
Temp.	55%	40%	45%	5%

Financial Factors

$/MBF	$650
Interest	6%
Term (years)	100
Storm Proffing $/mile	$18,000

;ide by Side Incremental Benefit Analysis of Watercourse and Lake Protection Zone Mitigations (Reduced Buffers) - Table 2

10/15/97

Proposed Mitigation	Impacted WLPZ Width Feet	Impacted Acres	Impact I On LTSY Total	mpact On LTSY MBF/Acre	Cost per Im Year	pact on Present Net Wotih	Percent Marginal Impact LWD	Marginal P Cost per Percent LWD	e r c Marginal Impact Sediment Delivery	e n t Cost p e r Percent Sediment Delivery	Marginal Marginal Impact Temp.	Percent Marginal Cost per Percent Temp.	Marginal Percent Total Function	Percentarginal Cart per Percent Total Function
re 1973 as % of Fully Functional							0.2%	1			30.0%			
PR over pre 1973														
lass 1 WLPZ 0 to 100'	100	8,140	4.651	0.79	$3,152,890	$34,055,642	24.3%	$209,9131	14.3%	5714,4641	21.7%	$864,995		
lass 2 WLPZ 0 to 75'	75	13.026	10,292	0.79	$6,689,621	$72,257,309	2.5%	$4,255,436	11.9%	$1,829,299	9.8%	$4,061,669		
		19.166	15,142		$9,842,511	$106,312,951	28.9%	$1,318,111	26.2%	$1,355,033	31.4%	$1,127,111	28.2%	$3,775,742
L over FPR							33.0%		26.2%		61.4%		40.2%	
lass 1 30' No Cut	30	1,642	1.901	1.(0.2	$1,235,614	$13,346,363	34.4%	$213,548	1.3%	$513,322	6.2%	$881,334		
lass 1 WLPZ WHR6 30 lo 10	70	4,298	660	0.2	$558,740	$6035177	2.6%	$1,082,349	0.3%	$1,207,035	0.9%	$2,977,883		
lass 2 WLPZ WHR6 0 to 75	75	13.026	2.606		$1,693,575	$18,292,990	2.9%	$3,128,811	0.8%	$1,219,533	3.3%	$2,458,735		
torm Proofing (50 miles/year)	50	Miles				$12,388,348			50.0%	$235,379				
			5,366		$3,487,929	$50,062,878	40.1%	$416,259	52.3%	$319,043	10.5%	$1,595,521	34.3%	$1,460,361
MFS Option 1 over PL							73.1%		78.5%		71.9%		74.6%	
lass 2 30' No Cut (40%)	30	2,084	2,151	1.032	$1,398,216	$15,102,692	2.1%	$4,001,195	0.5%	$1,510,269	1.2%	$4,967,991		
lass 2 WLPZ 100 to 130'	30	5,211	3,646	0.7	$2,371,005	$25,610,185	0.1%	$71,139,404	1.3%	$6,146,444	3.7%	$3,766,204		
lass 1 WLPZ 100 to 170'	70	4,298	3,009	0.7	$1,955,590	$21,123,120	1.1%	$2,912,195	2.6%	$2,634,774	7.8%	$1,484,882		
lass 2 WLPZ 75 to 100'	25	4,343	3,040	0.7	$1,975,636	$21,341,621	0.2%	$14,617,686	2.0%	$3,201,273	3.0%	$3,912,667		
0 Year WLPZ cutting Cycle		31,626	6,666	0.274	$5,632,947	$60,843,740	5.0%	$6,084,374	2.6%	$1,216,875	1.6%	$17,112,302		
last I Slope Distance	13	798	559	0.7	$363,181	$3,922,865					0.0%			
lass 2 Slope Distance	10	1,737	1,216	0.7	$790,335	$8,536,728					0.8%	$5,988,776		
hannel Migration Zone		2,000	3,408	1.704	$2,215,200	$23,927,272	1.4%	$9,400,000	2.7%	$443,098	3.1%	$3,087,390		
torm Proofingmiles/year)	50	Miles				$8,741,024			10.0%	$830,397				
		18,367	25,696		$16,702,311	$189,149,449	9.6%	$8,408,615	21.5%	$2,939,091	21.3%	$2,984,800	17.5%	$10,798,050
MFS Option 2 over PL							83%		100%		93%		92.0%	
lass 2 30' No Cut (40%)	30	2,084	2,151	1.032	$1,398,216	$15,102,692	2.1%	$4,001,195	0.5%	$1,510,269	1.2%	$4,967,991		
lass 2 WLPZ 100 to 170' (503	70	6,080	4,256	0.7	$2,766,173	$29,878,550	0.1%	$40,929,620	1.0%	$8,963,565	2.5%	$6,521,112		
lass 1 WLPZ 100 lo 170	70	4,298	3,009	0.7	$1,955,590	$21,123,120	1.1%	$2,912,195	2.5%	$2,534,774	7.8%	$1,484,882		
lass 2 WLPZ 75 lo 100	25	4,343	3,040	0.7	$1,975,638	$21,341,621	0.2%	$14,617,686	2.0%	$3,201,273	3.0%	$3,912,667		
0 Year WLPZ cutting Cycle		34,582	9,475	0.274	$6,159,054	$66,526,439	5.0%	$6,652,644	2.5%	$1,330,529	1.6%	$18,710,561		
lass1 Slope Distance	13	798	559	0.7	$363,181	$3,922,865					0.0%			
lass 2 Slope Distance	10	1,737	1,216	0.7	$790,335	$8,536,728					0.8%	$5,988,776		
hannel Migralion Zone		2,000	3,408	1.704	$2,215,200	$23,927,272	1.4%	$9,400,000	2.7%	$443,098	3.1%	$3,087,390		
torm Proofing (50 miles/year)	50	Miles				$8,741,024			10.0%	$830,397				
		19,255	27,113		$17,623,586	$199,100,512	9.9%	$6,708,132	21.2%	$3,130,198	20.0%	$3,310,726	17.0%	$11,660,532
MFS Option 3 over PL							83%		100%		92%		91.5%	
lass 2 30' No Cut	30	5,211	5,378	1.032	$3,495,539	$37,756,730	5.2%	$4,020,951	1.3%	$1,510,269	3.0%	$4,961,463		
lass 1 WLPZ 100 lo 170	70	4,298	3,009	0.7	$1,955,590	$21,123,120	1.1%	$2,912,195	2.5%	$2,534,774	7.8%	$1,484,882		
lass 2 WLPZ 75 to 100'	25	4,343	3,040	0.7	$1,975,838	$21,341,821	0.2%	$14,617,686	2.0%	$3,201,273	3.0%	$3,912,667		
0 Year WLPZ cutting Cycle		22,944	6,287	0.274	$4,086,326	$44,136,067	5.0%	$4,413,807	2.7%	$811,362	1.1%	$18,056,482		
lass 1 Slope Distance	13	798	559	0.7	$363,181	$3,922,865					0.0%			
lass 2 Slope Distance	8	1,390	973	0.7	$632,268	$6,829,383					1.6%	$2,401,637		
hannel Migration Zone		2,000	3,408	1.704	$2,215,200	$23,927,272	1.4%	$9,400,000	2.9%	$408,315	3.1%	$3,087,390		
torm Proofing (50 miles/year)	50	Miles				$8,741,024			10.0%	$830,397				
		12,828	22,652		$14,723,942	$167,760,282	12.9%	$4,344,573	21.4%	$2,613,139	19.6%	$2,848,470	18.0%	$9,337,614
							86%		100%		92%		92.5%	

hysical Factors	Acres	MBF/Acre
lass 1 acres per foot	61.4	
lass 2 acres per foot	173.7	
latrix lo Selection (150 BA)		0.79
VHR6 lo No Cut		1.032
latrix to WHR6		0.7
latrix lo No Cut		1.704
0 year cutting cycle		0.274
hannel Migration Zone		2,000

Relative Contribution to Stream Function

	LWD	Sediment	Shade
Class 1	85%	60%	60%
Class 2	15%	60%	40%

Relative Contribution of mitigations to function

	Zone Width	Zone No Cut	Prescription	Roads
LWD	15%	65%	50%	0%
Sediment	30%	6%	5%	95%
Temp.	55%	40%	45%	5%

Financial Factors

$/MBF	$650
Interest	6%
Term (years)	100
Storm Proffing $/mile	$18,000

Summary of Results for Temperature/Canopy Incremental Benefit Analysis

Treatment Introduction/assumptions/approach	Footnote # T1-T8	Class I Canopy	Class II Canopy	Class I % Increase	Class II % Increase	Class I % Functional	Class II % Functional
Pre-1973	T9	30	30	0.00	0.00	32.61	32.61
Post 73 Class I	T10	63.2	30	36.09	0.00	68.70	32.61
Post 73 Class II	T11	63.2	52.5	0.00	24.46	68.70	57.07
PL 30 ft no cut	T12	72.7	52.5	10.33	0.00	79.02	57.07
PL Class I late seral to 100 fi.	T13	74.1	52.5	1.52	0.00	80.54	57.07
PL Class I late seral 100 to 170 A.	T14	86.1	52.5	13.04	0.00	93.59	57.07
PL Class 2 late seral to 75 ft.	T15	86.1	60.2	0.00	a.37	93.59	65.43
PL Class 2 tare seral 75 to 100 ft.	T16	86.1	67. I	0.00	7.50	93.59	72.93
PL Storm Proofing	N/h	86.1	67.1	0.00	0.00	93.59	72.93
NMFS Opt. I 30 ft no cut Class IIs	T17	86.1	69.9	0.00	3.04	93.59	75.98
NMFS Opt. I Class II late seral 100-130	T18	86.1	78.5	0.00	9.3s	93.59	85.33
NMFS Opt. I SO year rotation	T19	87.4	00.5	1.41	2.17	95.00	87.50
NMFS Opt. I Class I slope distance	T20	87.4	80.5	0.00	0.00	95.00	87.50
NMFS Opt. I Class II slope distance	T21	87.4	02.3	0.00	I.96	95.00	R9.46
NMFS Opt. 1 Channel Migration Zone	T22	90.4	as. 1	3 . 2 6	3.04	98.26.	92.30
NMFS Opt. 1 Increased storm proofing.	N/A	90.4	85.1	0.00	0.00	98.26	92.50
NMFS Opt. 2 30 ft no cut Class IIs	T17	86.1	69.9	0.00	3.04	93.59	75.98
NMFS Opt. 2 Class II late seral 100-170	T23	86.I	75.7	0.00	6.30	93.59	02.28
NMFS Opt. 2 50 year rotation	T24	117.4	77.6	I.41	2.07	95.00	84.35
NMFS Opt. 2 Class I slope distance	T-20	87.4	77.6	0.00	0.00	95.00	84.35
NMFS Opt. 2 Class II slope distance	T25	87.4	79.4	0.00	1.96	95.00	86.30
NMFS Opt. 2 Channel Migration Zone	T26	90.4	82.1	3.26	2.93	98.26	89.24
NMFS Opt. 2 Increased storm proofing.	N/A	90.4	82.1	0.00	0.00	98.26	89.24
NMFS Opt. 3 30 h no cut Class IIs	T27	86. I	74.1	0.00	7.61	93.59	80.54
NMFS Opt. 2 SO year rotation	T-28	07.4	74.9	1.41	0.87	95.00	81.41
NMFS Opt. 2 Class I slope distance	n o	07.4	‘14.9	0.00	0.00	95.00	81.41
NMFS Opt. 2 Class II slope distance	T29	87.4	78.5	0.00	3.91	95.00	l-35.33
NMFS Opt. 2 Charnel Migration Zone	T30	90.4	81.2	3.26	‘2.93	98.26	08.26
NMFS Opt. 2 Increased storm proofing.	N/A	90.4	81.2	0.00	0.00	98.26	88.26
Fully Functional Canopy		92	92				

Summary of Results for LWD Incremental Benefit Analysis

Treatment	Footnote #	Class I LWD Places	Class II LWD Pieces	Class I % Increase	Class II % Increase	Class I % Functional	Class II % Functional
Introduction/assumptions/approach	CI-C3						
Pre-1973	C2	3.30	3.38	0.00	0.00	6.16	6.16
Post 73 Class 1	C4	19.1	3.30	28.63	0.00	34.79	6.16
Post 73 Class 1	C5	19.1	12.7	0.00	16.90	34.79	23.13
PL 30 A no cut	C6	41.3	12.7	46.44	0.00	75.23	23.13
PL Class 1 late seral lo 100 ft.	c7	43.1	12.7	3.26	0.00	78.51	23.13
PL Class 1 late seral 100 to 170 ft.	c7	43.0	12.7	1.28	0.00	79.70	23.13
PL Class 2 late seral 10 75 H.	C8	43.0	23.4	0.09	19.49	79.70	42.62
PL Class 2 late seral 75 lo 100 ft.	C8	43.0	24.2	0.06	1.46	79.70	44.08
PL Storm Proofmg	N/A	43.0	24.2	0.06	0.00	79.70	44.08
NMFS Opt. 1 30 ft no cut Class Us	C9	43.8	31.0	0.00	13.04	79.70	57.92
NMFS Opt. 1 Class II late seral 100-I 30	C10	43.0	32	0.00	0.36	79.70	58.29
NMFS Opt. 1 50 year rotation	C11	45.9	36.1	3.83	7.47	03.61	65.76
NMFS Opl. 1 Class I slope distance	C12	45.9	36.1	0.00	0.00	03.61	65.76
NMFS Opl. 1 Class II slope distance	C13	45.9	36.1	0.00	0.0-O	03.61	65.76
NMFS Opt. 1 Channel Migration Zone	C14	40	37.7	3.83	2.91	07.43	60.67
NMFS Opt. 1 Increased storm proofing.	N/A	40	37.7	0.00	0.00	07.43	68.67
NMFS Opt. 2 30 ft no cut Class IIs	C9	43.0	31.8	0.00	13.04	79.70	57.92
NMFS Opt. 2 Class II late seral 100-170	C15	43.0	32.2	0.00	0.73	79.70	50.65
NMFS Opt. 2 50 year rotation	C16	45.9	36.2	3.03	7.29	03.61	65.94
NMFS Opt. 2 Class I slope distance	C12	45.9	36.2	0.00	0.00	03.61	65.94
NMFS Opt. 2 Class II slope dislance	C13	45.9	36.2	0.00	0.00	03.61	65.94
NMFS Opt. 2 Channel Migration Zone	C17	40	37.0	3.03	2.91	07.43	60.05
NMFS Opt. 2 Increased slorm proofing.	N/A	40	37.0	0.00	0.00	07.43	60.85
NMFS Opt. 3 30 fl no cut Class IIs	C9	43.0	43.1	0.00	34.43	79.70	70.51
NMFS Opt. 2 50 year rotation	C10	45.9	45	3.03	3.46	03.61	01.97
NMFS Opt. 2 Class I slope dislance	C12	45.9	45	0.00	0.00	03.61	01.97
NMFS Opt. 2 Class II slope dislance	C13	45.9	45	0.00	0.00	03.61	01.97
NMFS Opt. 2 Channel Migration Zone	C19	40	47	3.83	3.64	07.43	05.61
NMFS Opt. 2 Increased storm proofing.	N/A	40	47	0.00	0.00	07.43	05.61
Fully Fundional LWD Recruitment		54.9	54.9				

Summary of Results for Sediment Incremental Benefit Analysis

Treatment	Footnote #	Class I Sediment	Class II Sediment	Class I % Increase	Class II % Increase	Class I % Functional	Class II % Functional
Introduction/assumptions/approach	S1-S7						
Pre-1973	S8	0	0	0.00	0.00	0.00	0.00
	s9						
Post 1973 Class I	S10	20.6	23.7	28.60	23.70	28.60	23.70
Post 1973 Class II		28.6	23.7	0.00	0.00	28.60	23.70
PL 30 A no cut	S11	31.2	23.7	2.60	0.00	31.20	23.70
PL Class I late seral to 100 ft.	S12	31.7	23.7	0.50	0.00	31.70	23.70
PL Class I late seral 100 to 170 ft.	S13	36.7	23.7	5.00	0.00	36.70	23.10
PL Class 2 late seral to 75 ft.	S14	36.7	25.2	0.00	1.50	36.70	25.20
PL Class 2 late seral 75 to 100 h.	S15	36.7	29.2	0.00	4.00	36.70	29.20
PL Storm Proofing	S16	86.7	19.2	SO.00	50.00	86.70	79.20
NMFS Opt. 1 30 ft no cut Class IIs	S17	86.7	80.2	0.00	1.00	86.70	80.20
NMFS Opt. I Class II late seral 100-130	S18	86.7	82.7	0.00	2.50	06.70	82.70
NMFS Opt. 1 SO year rotation	S19	89.2	85.2	2.50	2.50	89.20	as.20
NMFS Opt. 1 Class I slope distance	S20	89.2	85.2	0.00	0.00	89.20	85.20
NMFS Opt. 1 Class II slope distance	S21	89.2	85.2	0.00	0.00	89.20	85.20
NMFS Opt. 1 Channel Migration Zone	S22	91.9	87.9	2.70	2.70	91.90	87.90
NMM Opt. I Increased storm proofing.	S23	100	100	8.10	12.10	100.00	100.00
NMFS Opt. 2 30 A no cut Class IIs	S17	86.7	80.2	0.00	1.00	86.70	80.20
NMFS Opt. 2 Class II late seral 100-170	S24	06.7	82.2	0.00	2.00	86.70	82.20
NMFS Opt. 2 50 year rotation	S25	89.2	84.1	2.50	2.50	89.20	84.70
NMFS Opt. 2 Class I slope distance	S20	89.2	84.7	0.00	0.00	89.20	84.70
NMFS Opt. 2 Class II slope distance	S26	89.2	84.7	0.00	0.00	89.20	84.70
NMFS Opt. 2 Channel Migration Zone	S27	91.9	87.4	2.70	2.70	91.90	87.40
NMFS Opt. 2 Increased storm proofing.	S28	loo	100	8.IO	12.60	100.00	100.00
NMFS Opt. 3 30 fi no cut Class IIs	S17	86.7	81.7	0.00	2.50	86.70	81.70
NMFS Opt. 2 50 year rotation	S29	89.2	84.2	2.72	2.72	09.20	84.20
NMFS Opt. 2 Class I slope distance	S20	89.2	84.2	0.00	0.00	89.20	84.20
NMFS Opt. 2 Class II slope distance	S21	89.2	84.2	0.00	0.00	89.20	84.20
NMFS Opt. 2 Channel Migration Zone	S27	91.9	86.9	2.93	2.93	91.90	86.90
NMFS Opt. 2 Increased storm proofing.	S28	100	loo	8.80	14.24	100.00	100.00
Fully Functional Reduction in Sediment		loo	100				

FOOTNOTES FOR INCREMENTAL BENEFIT ANALYSIS

Evaluation of Canopy/Temperature

Tl : Temperature is the variable of concern in evaluating logging impacts to riparian function. However, by agreement with the agencies, canopy cover is being used as a surrogate variable to assess the likely effectiveness of various HCP proposals to protect water temperatures. This was done because: I) stream shading from the riparian canopy is a major determinant of water temperatures (i.e., the variables are directly related); 2) more extensive datasets are available for canopy cover as a function of riparian vegetation than for temperature; and 3) PL cannot manage for temperatures, which are strongly influenced by site specific variables (e.g., distance from ocean, air temperatures, stream discharge, etc.), but it can manage for canopy cover.

T2: The datasets used to assess the effects of buffer width on canopy levels were from studies that examined angular canopy density. ACD involves measuring canopy density at an angle to the buffer corresponding to the angle of the sun above the horizon (Beschta et al. 1987). The canopy density variable contained in NMFS' and PL's HCP proposals, by contrast, are vertical measurements through the buffer (also referred to as canopy closure). For a given stand ACD will therefore tend to be higher than canopy closure, but it is likely a more accurate estimate of canopy closure provided to the stream. Any bias in using ACD should affect both PL and NMFS' proposals equally.

T3: NMFS has requested a canopy closure of 70 percent for riparian buffers on PL's lands [letter of 20 August 1997 from Vicki Campbell (NMFS) to Tom Herman (PL)]. CDF conducted a monitoring study to determine canopy closure along Class I and Class II streams under current forest practices rules. This audit found that canopy closure under existing rules averaged over 70 percent along both Class I and Class II streams (Attachment 1). Nothing in PL's proposal would reduce canopy levels below those required by current rules, so it is reasonable to conclude that PL's plan will provide at least as much. canopy as observed in CDF's study. Accordingly, without further analysis it is possible to conclude that PL's proposals will result in 100 percent of the stream function for temperature being requested by NMFS (i.e., a canopy closure of 70 percent). By extension, this also indicates that NMFS' proposals for riparian zone management will not increase stream function with respect to temperature.

T4: R2 recognizes that the effects of canopy in protecting temperatures does not cease as canopy closure rises above 70 percent. Therefore, and even though PL's proposals will meet canopy levels requested by NMFS, R2 conducted an analysis to try and evaluate the overall benefit of PL and NMFS' proposals under the assumption that maximum temperature protection occurs at canopy levels present in large, unmanaged buffers.

T5: R2 previously provided NMFS with a scattergram showing canopy density as a function of stream buffer width (Presentation of 26 September). That original scattergram has been expanded to include data from Erman et al. 1977 (Figure 1). Erman et al. included data for a large number of unmanaged forests in Northern California. Although unmanaged forests generally have a continuous canopy extending for hundreds of feet, the buffer width for Erman et al.'s unmanaged sites was set at 150 ft because: a) FEMAT (1994) indicated that maximum canopy closure occurs with a buffer equivalent to 0.75 * site potential tree height (about 130 ft. for PL lands), and b) equations in Platts et al. (1987) were used to calculate that the length of shadows cast by site potential trees on PL's land are 76-119 ft during the summer hours of 1000-1400 when most solar heating occurs. The revised Figure 1 shows that even clearcut streams typically have 20-30 percent canopy density, primarily from understory plants and non-merchantable trees that are not removed during harvest In addition, data from Erman et al. demonstrate that unmanaged streams often contain canopy density levels less than 100 percent (their average value was approx. 75 percent). Values less than 100 percent for unmanaged forests are likely the result of "holes" in the canopy, wide stream widths and SE to SW aspect, all of which reduce the amount of shading provided by riparian vegetation..

T6: Data outliers in T1 were eliminated as follows: 1) Canopy values less than 70 percent for unmanaged streams were deleted, and 2) a value of 0 percent canopy for a stream with a 72 ft wide buffer was deleted. A 2nd order polynomial equation was then fitted to the remaining points (Figure 2). The resulting curve had an R^2 value of 0.64. If the outliers were not removed the curve would have predicted that unmanaged forests have lower canopy density than the levels shown in Figure 2. Thus, removal of outliers is conservative in that it accords more canopy benefit to unmanaged forests than is likely to actually occur.

T7: Figure 2 was used to calculate the maximum canopy density expected as a function of buffer width. Note that the canopy density expected at 150 feet is approximately 92 percent. Since, as noted in T5 above, canopy density is expected to reach a maximum at 150 ft. or less, this indicates that canopy density under unmanaged conditions is equal to 92 percent. This is the baseline canopy level used throughout this analysis.

T8: 1) Figure 2 calculates canopy density expected in unmanaged forest buffers of varying widths. However, both existing rules and many of the riparian prescriptions proposed by PL and NMFS call for tree densities less than those in unmanaged forests, in additional factor or scalar is needed to reduce values obtained from Figure 2 to account for reduced tree density.

2) The relationship between tree density and canopy cover is not linear, except over small changes in canopy. This is true because as tree density goes up, it becomes increasingly likely that the shade contributed by an individual tree will overlap with the shade provided by other trees. Thus, increases in tree density over one range (e.g., 90-100 trees/acre) are likely to produce less additional canopy cover than would the same unit increase in tree density at a lower range (e.g., 60-70 trees/acre). This type of mathematical relationship can be described using curves that rise rapidly over small changes from zero before gradually leveling out into an asymptote (e.g., exponential curves).

3) Figure 3 shows a curve relating tree density to canopy cover expected under unmanaged conditions. To develop this curve several "known" points were used: a) zero trees results in zero canopy (note, zero trees is not the same as zero buffer), b) existing rules for Class II streams result in 67 trees/acre (from Table 4) that produce (from Attachment I) 70.3 percent canopy, c) existing rules for Class I streams result in 98 trees/acre (from Table I) and produce (from Attachment 1) 70.9 percent canopy, and d) unmanaged forests produce up to 92 percent canopy (from Figure 1) and contain 273 trees acre (from Table 2). Rather than plot these values directly, they were converted so that the y axis of the resulting graph would be percent of canopy expected under unmanaged conditions'. This conversion involved taking each of the canopy values in b-d above, dividing by 92 and multiplying times 100 percent.

T9: 1) Prior to 1973 no buffer along Class I streams was required. R2 assumed that this meant that no riparian buffer was retained. From Figures 1 and 2, even when buffer width was zero, canopy density was 20-30 percent. The curve endpoint of 30 percent was selected as the canopy cover for stream channels on PL's ownership prior to 1973.

T10: 1) The 1973 Forest Rules require retention of 100 ft wide buffers along Class I streams. From Figure 2, a 100 ft wide buffer consisting of unmanaged forest would be expected to result in a canopy density of 78 percent.

2) Table 1 includes PL data from stand exams in Class I Watercourse and Lake Protection Zones (WLPZs) following harvest. Results in Table 1 indicate current rules result in an average retention of 98 trees/acre following harvest. From Figure 3, a forest stand of 98 trees/acre is expected to produce 81 percent of the canopy produced by an unmanaged stand.

3) Estimated canopy along Class I streams resulting from existing rules can therefore be calculated as:

Canopy- (Canopy of an unmanaged stand of equivalent width) * (Proportion of unmanaged canopy expected at the given tree density)

= (78 percent) * .81 = 63.2 percent canopy

4) The functional value of this can be determined by dividing by the canopy level associated with full function (i.e., 92 percent) and multiplying by 100 percent. That is:

Functional Value = [(63.2 percent) /(92 percent)] * 100 percent = 68.7 percent

Tl 1: 1) The 1973 Forest Rules require retention of 75 ft wide buffers along Class II streams. From Figure 2, a 75 ft wide buffer consisting of unmanaged forest would be expected to result in a canopy density of 70 percent.

2) From Table 4, current forest practices rules result, post-harvest, in stand densities in Class II stream WLPZs of 67 trees/acre. From Figure 3, a forest stand of 67 trees/acre is expected to produce 75 percent of the canopy produced by an unmanaged stand.

3) Estimated canopy along Class II streams resulting from existing rules can therefore be calculated as:

Canopy = (70 percent) * .75 = 52.5 percent canopy

T12: 1) The 30 ft no-cut buffer does not add buffer onto that already required by the 1973 rules. Instead PL's proposal will convert the first 30 ft. of that buffer from a partially harvested stand to one without harvest. From Figure 2, a 30 ft wide buffer consisting of unmanaged forest would be expected to result in a canopy density of 50 percent. This is the canopy expected to result from the 30 ft no cut buffer.

2) Although 30 ft of the Class I buffer has been converted to no-cut in this scenario, the remaining 70 ft of buffer (i.e., from 30 ft to 100 ft) with stands determined by current rules still contributes some canopy. From Figure 2, a 100 ft wide buffer is expected to provide 78 percent of the canopy expected under unmanaged conditions, and a 30 ft wide buffer would provide 50 percent. Thus, a buffer extending from 30 to 100 ft could be expected to provide 78 - 50 = 28 percent canopy.

3) From Figure 3, a forest stand of 98 trees/acre is expected to produce 81 percent of the canopy produced by an unmanaged stand. Thus, canopy expected from the remaining 70 ft of buffer is:

Canopy= (28 percent) * .81 = 22.7 percent canopy

4) So the overall canopy expected to result from this proposal is 50 percent plus 22.7 percent = 72.7 percent.

T13: 1) The benefit of upgrading to late seral buffers from 30 ft -70 ft can be easily calculated- From Table 3, PL's WHR 6 prescription is expected to result in 124.3 trees/acre. From Figure 3, 124.3 trees/acres is expected to result in 86 percent of the canopy expected under unmanaged conditions. Therefore, the expected canopy density is:

Canopy= (28 percent) * .86 = 24.1 percent canopy

2) So the overall canopy expected to result from this proposal is 50 percent (from 30 ft no cut) plus 24.1 percent = 74.1 percent.

T14: 1) The benefit of an additional 70 ft of buffer can be calculated as follows. From Figure 2, a 100 A wide buffer is expected to provide 78 percent of the canopy expected under unmanaged conditions. As discussed in T5, any buffer over 150 ft is assumed to provide full canopy closure, or 92 percent. Thus, a buffer extending from 100 to 170 ft could be expected to provide 92-78 = 14 percent canopy.

2) From Figure 3, 124.3 trees/acre is expected to result in 86 percent of the canopy expected under unmanaged conditions. Therefore, the expected canopy density is:

Canopy= (14 percent) * .86 = 12 percent canopy

3) So the overall canopy expected to result from this proposal is 74.1 percent (from 30 ft no cut and 70 ft late seral) plus 12 percent = 86.1 percent,

T15: 1) From Figure 2, a 75 ft wide buffer consisting of unmanaged forest would be expected to result in a canopy density of 70 percent.

2) From Table 3, PL's WHR 6 prescription is expected to result in 124.3 trees/acre. From Figure 3, 124.3 trees/acre is expected to result in 86 percent of the canopy expected under unmanaged conditions. Therefore, the expected canopy density is:

Canopy- (70 percent) * .86 = 60.2 percent canopy

T16: 1) From Figure 2, a 100 ft wide buffer consisting of unmanaged forest would be expected to result in a canopy density of 78 percent.

2) From Table 3, PL's WHR 6 prescription is expected to result in 124.3 trees/acre. From Figure 3, 124.3 trees/acre is expected to result in 86 percent of the canopy expected under unmanaged conditions. Therefore, the expected canopy density is:

Canopy= (78 percent) * .86 = 67.1 percent canopy

T17: 1) NMFS Option 1 requires a 30 ft. no harvest zone where slopes along redwood dominated Class II streams exceed 50%, and along all Douglas fir dominated streams. PL has estimated that this would affect 40 percent of all Class II stream mileage.

2) From Tl6, item 2, canopy cover along Class II streams if PL's proposals are implemented is 67.1 percent,

3) From T12, item 1, a 30 ft wide buffer consisting of unmanaged forest would be expected to result in a canopy density of 50 percent.

4) From T13, item 1, a late seral buffer extending from 30-100 ft would provide 24.1 percent canopy.

5) So the overall canopy expected where no cut buffers are present is 50 percent plus 24.1 percent = 74.1 percent.

6) The no-cut buffer will only be present on 40 percent of all Class II stream miles so the average expected canopy is therefore: (.4*74.1)+(.6*67.1) = 69.9 percent.

T18: 1) NMFS Option 1 requires an increase in the total width of the late seral buffer along Class II streams from 100-130 ft.

2) From Figure 2, a 100 A buffer provides 78 percent canopy cover, and a 130 ft buffer provides 88 percent canopy. Thus, a buffer extending from 100 to 130 ft could be expected to provide 88 - 78 = 10 percent canopy.

3) From Figure 3, a forest stand of 124.3 trees/acre is expected to result in 86 percent of the canopy expected under unmanaged conditions. Thus, canopy expected from the increased buffer width is:

Canopy= (10 percent) * .86 = 8.6 percent canopy

4) So the overall canopy expected would be :

(.4 * (74.1 + 8.6)) + (.6 * (67.1 + 8.6)) = 78.5 percent

T19: 1) Obtaining data to calculate the effect of a 50 year cutting cycle would require significant modifications to PL's stand typing and sustained yield timber model. These modifications were not made. However, Vestra Resources (PL's GIS contractor) did analyze the effects of 60 years without harvest on existing riparian stands. This was done to determine the future stand conditions of PL's LMZ. This analysis indicated that tree density would increase 44.8 percent in 60 years. Assuming direct proportionality, this means that a 20 year rotation length would result in (20/60)* 44.8 = 14.9 percent increase in tree density, and a 50 year rotation would result in (50/60)* 44.8 = 37.3 percent increase. Thus a 50 year rotation would result in a net of 37.3-14.9 = a 22.4 percent difference in tree density compared to PL's proposal.

2) From Table 3, PL's late seral prescription with a 20 year re-entry interval is expected to result in 124 trees acre. The 50 year rotation is therefore estimated to result in 124 * 1.224 = 151.7 trees acre.

3) From Figure 3, 124 trees acre is predicted to result in a canopy density of 86 percent while 152 trees/acre would result in a canopy of 89 percent.

4) For Class I streams: the 30 ft no cut buffer provides 50 percent canopy. From Figure 2, additional canopy extending from 30 ft to 170 ft would be expected to produce 92 percent - 50 percent = 42 percent canopy. Thus, the predicted canopy for Class I streams is:

(SO percent) + (42 percent * .89) = 87.4 percent.

5) For Class II streams: 40 percent of the buffers have a 30 ft no cut zone that provides SO percent canopy and a late seral buffer from 30-130 ft. From Figure 2, an unmanaged buffer extending from 30-l30 ft is expected to produce 88-50 = 38 percent canopy. Thus total canopy for the 40 percent of Class II streams with a 30 ft. no cut buffer is:

(50 percent) + (38 percent * .89) = 83.8 percent,

6) For the 60 percent of all Class II streams without a 30 ft no cut buffer, canopy density is:

(88 percent) * .89 = 78.3 percent.

7) Thus, the total canopy for Class II streams is:

(.40 * 83.8 percent) + (.60 *78.3 percent) = 80.5 percent.

T20: 1) Assuming an average slope of 40 percent (PL estimate), this requirement would add 13 ft onto the total width of the Class I buffer. That is, buffer width would increase from 170 ft to 183 ft. However, as discussed in T5, any increase in buffer width beyond 150 ft has no impact on predicted canopy levels. Thus this requirement has no incremental benefit for canopy.

T21: 1) Assuming an average slope of 40 percent, this requirement would add 10 ft onto the total width of the Class II buffer. That is, buffer width would increase from 130 ft to 140 ft. From Figure 2, a 130 ft wide buffer is expected to provide 88 percent canopy under unmanaged conditions, and a 140 ft wide buffer would provide 90 percent. Thus, a buffer extending from 130-140 ft could be expected to provide 90-88 = 2 percent canopy.

2) From Figure 3, a forest stand of 151.7 trees/acre is expected to result in 89 percent of the canopy expected under unmanaged conditions. Thus, canopy expected from the 10 ft of additional buffer is:

Canopy= (2 percent) * .89 = 1.8 percent canopy

3) So the overall canopy expected if horizontal distance is used to measure Class II buffers is 80.5 percent plus 1.8 percent = 82.3 percent.

T22: 1) Establishment of a no harvest, channel migration zone would increase canopy closure above levels established above only if the lateral movement of streams were enough to significantly reduce the size of the riparian buffers in the migration zone. To date, no data on significant lateral movements beyond the permanent vegetation line (as defined in the California Forest Practices Rules) have been presented by the agencies. Nor have data documenting channel avulsions (channel "jumping") been presented. Similarly, specific sites and the total area to be included for channel migration zones have not been identified. Consequently, quantitative analysis of the benefits of this measure is difficult.

2) Most channels on PL's ownership are partially or totally contained within valleys, which would limit or prevent channel migration (as Keller et al. 1995 found for confined channels in their unmanaged redwood forest streams). Thus, the benefit of channel migration would be limited to lower gradient, unconfined stream channels.

3) Keller et al. (1995) used the ages of streamside trees to reconstruct the history of channel migration along Prairie Creek. This floodplain stream flows through an unmanaged redwood forest north of PL's ownership. They found lateral migration was as low as "one channel width in the last several hundred to 1,000 years." Some meander cutoffs and abandoned channels were observed, but the former were "fairly rare," and the latter were limited to "several instances" along the 6.5 miles of channel they surveyed. Data from one stream are not definitive evidence, but the data in Keller et al. clearly indicate that low gradient, alluvial channels in redwood forest can have very small channel migration rates.

4) Despite uncertainty regarding the location or likelihood of channel migration, PL has assumed that a total of 2,000 acres of riparian forestland would need to be set aside to satisfy NMFS' request for channel migration zone buffers. If this estimate is correct, the potential benefit of the channel migration buffers can be at least qualitatively demonstrated.

5) The increased width of the riparian buffer in the channel migration zones is unknown- R2 assumed that they would be equal to the most conservative riparian

protection strategy we are aware of, the two site-potential tree, no-cut buffer proposed in FEMAT (1993). If two site potential trees is equal to 340 ft, and 30 ft of this buffer is already no-cut (the 40 percent of Class. II streams without no cut buffers under NMFS Options 1 and 2 was ignored), then for both sides of the stream the total width of new, no cut buffer is 620 ft. The 2,000 acres of channel migration zone buffer would therefore provide full protection for 26.6 miles of stream as calculated below:

Miles = ((2,000 acres * 43,560 square ft/acre)/620 ft wide buffer)/5280 ft/mile

6) From PL's SYP/HCP, page 18, the ownership contains 969.8 miles of Class I and Class II streams. The extra channel protected by the channel migration zone buffers is therefore 2.7 percent of all stream miles.

7) The most conservative assumption is that all 26.6 miles of stream protected by the channel migration zones would migrate completely out of their 100-170 ft buffers without this additional protection If we additionally assume that the forest outside the buffers would provide no canopy cover (e.g., had just been clearcut) then average canopy levels with only PL's proposalsin place would equal (.973 * 76.6 percent) = 74.5 percent canopy (.973 is the proportional fraction of stream miles still retaining canopy, and 76.6 percent is the average canopy expected to result along Class I and II streams if all of PL's proposals are implemented (from T14 and T16 above)). The channel migration zones would provide (.027 * 92 percent) = 2.5 percent more shade (.027 is proportional fraction of stream miles that would have canopy "restored" with CMZs, and 92 percent is the assumed canopy closure in the CMZs). We used canopy improvements over those proposed by PL rather than those proposed by each of NMFS' three options. This was done for simplicity. However, this is conservative in that it exaggerates the benefit of NMFS' channel migration zones.

8) Thus the benefit of channel migration zones can be estimated as (2.5/74.5) = 3.4 percent more canopy cover, on average, then if only PL's proposals are implemented. Thus for Class I streams canopy can be estimated as 87.4 * 1.034 = 90.4 percent, and the benefit for Class II streams can be estimated as 82.3 * 1.034 = 85.1 percent

T23: 1) From Figure 2, a 100 ft buffer provides 78 percent canopy cover, and from T5 a 170 ft buffer provides 92 percent canopy. Thus, a buffer extending from 100 to 170 ft could be expected to provide 92 - 78 = 14 percent canopy.

2) From Figure 3, a forest stand of 124.3 trees/acre is expected to result in 86 percent of the canopy expected under unmanaged conditions. Thus, canopy expected from the increased buffer width is:

Canopy= (14 percent) * .86 = 12 percent canopy

3) So the overall canopy expected would be 69.9 percent + 12 percent = 81.9 percent.

4) However, the 170 ft canopy would only apply to 50 percent of all Class 2 streams (PL estimate), so the composite buffer level can be calculated as:

(.50 * 69.9 percent canopy) + (.50 * 81.5 percent canopy) = 75.7 percent canopy

T24: 1) From T19 above, the predicted canopy for Class I streams is 87.4 percent.

2) Under NMFS Option 2, approximately 40 percent of the Class II streams have no cut buffers and 60 percent do not. In addition; 50 percent of the streams have 170 ft buffers and 50 percent do not. So there are four possible treatments: 30 ft no cut plus 100 ft buffer, 30 ft no cut plus 170 ft, 100 ft late seral buffer, and 170 ft late seral buffer. For the group with a 30 ft no cut buffer and 100 ft wide buffer:

Canopy- (50 percent) + (28 percent + .89) = 74.9 percent

3) Canopy for a 30 ft no cut buffer with a 170 ft wide buffer is the same as in 1 above = 87.4 percent.

4) For Class IIs containing a 170 ft wide buffer with 50 year rotation, late seral stands, expected canopy is:

92 percent * .89 = 81.2 percent

5) For Class IIs containing a 100 ft wide buffer with 50 year rotation, late seral stands, canopy is:

78 percent * .89 = 69.4 percent

6) So average canopy for all Class II streams is:

(.20 * 74.9 percent) + (.20 * 87.4 percent) + (0.30 * 81.2 percent) + (0.30 * 69.4 percent)= 77.6 percent.

T25: I) Under Option 2, 50 percent of all Class II streams have a buffer of 170 ft. Therefore, as for Class I streams, additional buffer width will have no effect on shading for this half of all Class IIs.

2) For the other 50 percent, assuming a 40 percent slope, this requirement would add 8 ft onto the width of 100 ft wide Class II buffer. From Figure 2, an increase in buffer width from 100 to 108 ft is expected to increase canopy from 78 to 82 percent, or an increase of 4 percent. Thus the extra canopy from this increase in width is equal to 4 percent * .89 = 3.6 percent.

3) So average canopy for all Class II streams is:

(.20 * (74.9 + 3.6 percent)) +(.20 * 87.4 percent) + (0.30 * 81.2 percent) + (0.30 * (69.4 + 3.6 percent))= 79.4 percent,

T26: 1) From T22 above, this requirement is expected to increase canopy cover by 3.4 percent. A 3.4 percent increase would take predicted canopy cover along Class I streams to 90.4 percent, and Class II streams to 79.4 percent.

T27: I) From T17, item 5, the canopy expected if all Class II streams have 30 ft no cut buffers is 74.1 percent.

T28: 1) From T19 above, the predicted canopy for Class I streams is 87.4 percent.

2) Under NMFS Option 3, all Class II streams have a 30 ft. no cut buffer and a late seral buffer extending from 30-100 ft. From T24, item 2, canopy is expected to be 74.9 percent for this buffer combination.

T29: 1) From TX above, a change in buffer width from 100 to 108 ft is expected to increase canopy by 3.6 percent. Thus Class II canopy would be 74.9 percent + 3.6 percent = 78.5 percent.

T30: 1) From T22 above, this requirement is expected to increase canopy cover by 3.4 percent. A 3.4 percent increase would take predicted canopy cover along Class I streams to 90.4 percent, and Class II streams to 81.2 percent.

Evaluation of Large Woody Debris Recruitment

C 1: 1) Several assumptions and approaches are used throughout this analysis. First, LWD levels are reported in pieces/100 ft of stream length wherever possible. This was done because a) the State reports LWD levels using these units, b) almost all LWD data for PL's lands and surrounding areas are reported in these units, c) most literature studies can be converted to these units. Second, the simplifying assumption was made that any LWD recruitment to streams remains there for the 60 years analyzed for the HCP. In reality, some LWD would be washed downstream or would decay over time, but estimating these loss and decay rates would be unnecessarily complex for the current analysis. Importantly, this bias affects all proposed measures, from both PL and NMFS, equally. Third, the benefits of no cut zones are assumed equal to those of unmanaged streams, even though it will take time to "grow" these zones into stands equivalent to stands in unmanaged systems. This was done because the intent of no-cut zones is clearly to provide a permanent strip of unmanaged forests along streams. This affects the two proposals differently. PL obtains more benefit for its proposed 30 ft. no cut buffer along Class I streams than is likely to occur during the HCP, and NMFS obtains more benefit for its proposed 30 ft Class II no cut buffers than will likely occur. Finally, the stand conditions-for all other treatments arc assumed equal to either existing conditions or to conditions expected immediately following harvest. This is done for pragmatic reasons; PL's timber model can accurately predict either current or post-harvest stand conditions but not conditions "mid-cycle." As before, the bias from this should apply equally.

C2: 1) It is assumed that pre-1973 rules resulted in clearcutting to the stream edge every 60 years (approximate rotation time, for site 2 redwood on PL's lands). Grette (1985) examined LWD levels in streams with varying management histories. He used these data to estimate LWD as a function of years since clearcut harvesting (his Figure 20, page 93). He estimated that 11.1 pieces of LWD equivalent in size to the average LWD piece observed in unmanaged forests would recruit to a 100 m stream reach over 60 years following clearcut harvesting. This equates to 3.38 LWD pieces/l00 ft. This LWD recruitment level was used for both Class I and Class II streams under pre-1973 rules.

C3: 1) The benefits of the remaining silvicultural treatments were determined by "discounting" from the estimated LWD levels, that would develop in a no cut buffer equivalent to 1 site potential tree in height (170 ft). That is, the baseline for determining benefits is unmanaged conditions.'

2) From Table 2, PL's Limited Management Zone or "no cut" buffer will result in stand conditions that, on average, contain 273 trees/acre. This estimate was obtained through stand modeling by Vestra Resources. Specifically, they modeled the effect of 60 years without harvest on the riparian stands currently present along PL's Class I streams.

3) Van Sickle and Gregory (1990), examined data on LWD recruitment in an unmanaged stream buffer equal to 164-213 ft. in width. They reported that 13 percent of all trees in the riparian zone they studied fell per decade and that overall 33 percent of these hit the stream. By simple multiplication, this translates to an estimate that 4.3 percent of all trees in the riparian zone recruit to the stream in a given decade. Recruitment rates vary with distance so this 4.3 percent estimate is most appropriate when used as the overall average for the buffer.

4) A total of 273 trees/acre are expected in the no cut buffer. This number of trees/acre was converted to the number along 100 ft of stream with a 170 ft wide buffer on each bank as follows:

100 ft (length) * 170 ft (width) = 17,000 ft^2
17,000 ft^2 / (43,560 ft^2 /acre) = 0.39 acres
0.39 acres * (273 trees/acre) = 106.5 trees in one 100 X 170 ft area
106.5 trees * 2 = 212.9 trees total in buffers along both sides of stream

5) Given the 212.9 trees calculated in item 4, and the recruitment rate of 4.3 percent from item 3, this equates to recruitment of 9.2 trees/decade per 100 ft of stream, or 54.9 trees/ 100 ft of stream for a 60 year period under unmanaged conditions.

C4: 1) Table 1 provides stand conditions present, post-harvest, along Class I streams given existing rules. A total of 98 trees/acre are expected.

2) Two types of "discounting" from LWD recruitment levels of unmanaged stands is needed. First, the effects of reduced tree density must be accounted for. Second, the effects of reduced buffer width must be calculated.

3) From Table 2,273 trees/acre are expected in the 170 ft. wide no cut buffer, and from item 1 above 98 trees/acre are expected under current rules. Therefore the change in LWD recruitment due to tree density changes can be calculated as: (98 / 273) = 0.359. That is, a 170 ft wide buffer managed under current rules is expected to have just 35.9 percent of the LWD recruitment that would be expected if the buffer was no cut.

4) Figure 4 shows how changes in buffer width were calculated by Van Sickle and Gregory (1990) to affect LWD recruitment. The y axis of their curve reports LWD recruitment as a function of the level expected from an unmanaged stream buffer equivalent in width to one site potential tree's height. From this curve, a buffer 170 ft. wide would provide 100 percent of potential LWD recruitment, and a buffer 100 ft wide would provide 97 percent of potential LWD recruitment. This is a measure of buffer "effectiveness".

5) Given items 4 and 5, then, the equation for discounting LWD recruitment from a 170 ft wide, unmanaged buffer to levels along Class I streams expected under current rules is:

[(trees in trt. /trees in unmanaged)* buffer effectiveness * unmanaged LWD recruitment]

[((98 trees) / (273 trees)) * 0.97 * 54.9 trees/100 ft] = 19.1 trees/100 ft

C5: 1) Table 4 provides stand conditions present, post-harvest, along Class II streams given existing rules. A total of 67 trees/acre are expected.

2) Again, two types of "discounting" from LWD recruitment levels of unmanaged stands is needed. First, the effects of reduced tree density must be accounted for. Second, the effects of reduced buffer width must be calculated.

3) From Table 2,273 trees/acre are expected in the 170 ft. wide no cut buffer, and from item 1 above 67 trees/acre are expected under current rules. Therefore the change in LWD recruitment due to tree density changes can be calculated as: (67 / 273) = 0.245. That is, a 170 ft wide buffer managed under current rules is expected

to have just 24.5 percent of the LWD recruitment that would be expected if the buffer was no cut.

4) From Figure 4, a buffer 170 ft wide would provide 100 percent of potential LWD recruitment, and a buffer 75 ft wide would provide 94 percent of potential LWD recruitment.

5) Given items 4 and 5, then, the equation for discounting LWD recruitment from a 170 ft wide, unmanaged buffer to levels expected along Class II streams under current rules is:

[((67 trees) / (273 trees)) * 0.94 * 54.9 trees/100 ft] = 12.7 trees/100 ft

C6: 1) The analysis in C4 applies except that the first 30 ft of the buffer now contains no cut conditions. Therefore the LWD expected from a 30 ft. *no* cut buffer along the stream must be calculated and added to a new estimate of the amount of LWD that would be generated under existing rules from a buffer that extends 30 ft to 100 ft from the stream.

2) Density of trees in the 30 ft. no cut is equal to that in the reference 170 ft wide no cut buffer so no discounting for tree density is required.

3) From Figure 4, a buffer 170 ft. wide would provide 100 percent of potential LWD recruitment, and a buffer 30 ft wide would provide 63 percent of potential LWD recruitment.

4) Given item 3, then, the equation for discounting LWD recruitment from a 170 ft wide, unmanaged buffer to levels expected under a 30 ft no cut buffer is:

[0.63 * 54.9 trees/100 ft] = 34.6 trees/100 ft

5) LWD recruitment for a 100 ft wide buffer under existing rules from C4, item 5, needs to be reduced because the first 30 ft of buffer has been replaced. From Figure 4, a buffer 100 ft wide provides 97 percent of all LWD, and a buffer 30 ft wide provides 63 percent of all LWD. Thus, LWD recruitment from the remaining 70 ft of buffer is:

((98 trees / 273 trees) * (.97 - .63) * 54.9 trees/100 ft] = 6.7 trees/100 ft

6) Combining 4 and 5, a 30 ft no cut buffer, combined with 70 additional feet under existing rules is expected to provide 41.3 trees/100 ft.

C7: 1) The analysis in C6 applies except that the buffer from 30-100 ft will be "upgraded" to late seral conditions, and an additional 70 ft of late seral buffer will be added.

2) From Table 3, the number of trees in PL's late seral buffer is 124 trees/acre.

3) The increased LWD recruitment from upgrading to a late seral buffer can be calculated using the same methods as in C6, item 5, that is:

[(124 trees / 273 trees) * (.97 - .63) * 54.9 trees/100 ft] = 8.5 trees/100 ft

So, recruitment expected with the upgrading of buffer from 30-100 ft is 43.1 trees/l00 ft.

4) From Figure 4, a 170 ft buffer provides 100 percent of LWD recruitment, and a 100 ft buffer provides 97 percent of potential recruitment. Therefore, the increased LWD recruitment from a late seral buffer extending from 100 ft to 170 ft can be calculated as:

[(124 trees / 273 trees) * (1 - .97) * 54.9 trees/100 ft] = 0.75 trees/l00 ft

5) So, combining C6, item 4, and items 3-4 above, total LWD recruitment expected from PL's proposal for a 30 ft no cut buffer and an additional 140 ft of late seral buffer is 34.6 + 8.5 + 0.75 = 43.8 trees/100 ft.

C8: 1) This PL proposal has two benefits, upgrading of the existing 75 ft buffer to late seral stand conditions, and an increase in buffer width from 75 to 100 ft.

2) From Table 3, the number of trees in PL's late seral buffer is 124 trees/acre.

3) From Figure 4, a 75 ft wide buffer provides 94 percent of all LWD recruitment, and a 100 ft buffer provides 97 percent.

4) LWD expected from upgrading the 75 ft buffer is therefore:

[(124 trees / 273 trees) * (.94) * 54.9 trees/100 ft] = 23.4 trees/100 ft

5) The increased LWD recruitment from upgrading to a late seral buffer and increasing buffer size 25 ft can be calculated using the same methods as in C6, item 5. That is:

[(124 trees / 273 trees) * (.97) * 54.9 trees/l00 ft] = 24.2 trees/100 ft

C9: 1) From C6, item 4, a 30 ft. no cut buffer would result in 34.6 trees/l00 ft.

2) From C8, item 4, PL's proposal for Class II streams would result in 24.2 trees/100 ft. This value needs to be reduced to account for the conversion of 30 ft. of buffer to

uncut conditions. Using methods in C6, item 6, recruitment from a late seral buffer extending from 30 to 100 ft can be calculated as:

[(124 trees / 273 trees) * (.97 - .63) * 54.9 trees/100 ft] = 8.5 trees/100 ft

3) Combining 1 and 2 above results in an estimate of 43.1 trees/100 ft

4) However, under NMFS Option 1, only 40 percent of streams would have a no cut buffer (PL estimate). Therefore, the average LWD recruitment potential expected over all Class II streams is:

(0.40 * 43.1 trees/l00 ft) + (0.60 * 24.2 trees/100 ft) = 31.8 trees/100 ft

C 10: 1) The expected increase in LWD recruitment from extending the late seral buffer along Class II streams from 100 to 130 ft can be calculated using methods similar to those used in C7, item 4:

[(124 trees / 273 trees) * (.98 - .97) * 54.9 trees/100 ft] = 0.25 trees/100 ft

2) Combining C9, item 4 and item 1 above indicates that LWD recruitment potential would equal 31.8 + 0.25 = 32 trees/100 ft

Cl 1: 1) As noted in T19, estimating the benefit of a 50 year cutting cycle is difficult because PL's timber model does not provide an estimate for this silvicultural prescription, and changing it to do so would be difficult and time consuming.

2) Following methods in T19, R2 estimated that a 50 year rotation would increase tree density in late seral buffers over those in PL's proposed 20 year rotation by 22.4 percent to 151.7 trees/acre.

3) Estimates for Class I and Class II streams must be done separately. For Class I streams, the benefit would be equal to the additional LWD recruitment expected in the late seral buffer that extends from 30 to 170 ft. From C7, items 3 and 4, the increased benefit could be calculated as:

[(151.7 trees / 273 trees) * (1 - .63) * 54.9 trees/l00 ft] = 11.3 trees/l00 ft

And the benefit from the 30 ft no cut buffer is 34.6 trees/100 ft. So a total of 45.9 trees/100 ft are expected to recruit into Class I streams if a 50 year rotation is used.

4) Two estimates are needed for Class II streams. The first is the additional LWD that would accrue for the 40 percent of Class II streams with a 30 ft no-cut buffer. The second is LWD benefits for the 60 percent of streams without a no-cut buffer. For case 1, and using methods outlined repeatedly above, the potential LWD

recruitment from a 50 year rotation, late seral buffer extending from 30 to 130 feet is:

[(151.7 trees / 273 trees) * (.98 - .63) * 54.9 trees/l00 ft] = 10.7 trees/l00 ft

And the benefit from the 30 ft no cut buffer is 34.6 trees/l00 ft. So a total of 45.3 trees/l00 ft are expected to recruit along 40 percent of Class II streams.

5) For the 60 percent of Class IIs containing a 130 ft wide buffer with 50 year rotation, late seral stands, LWD recruitment, is:

[(151.7 trees / 273 trees) * (.98) * 54.9 trees/l00 ft] = 29.9 trees/100 ft

6) So average LWD recruitment for all Class II streams is:

(0.40 * 45.3 trees/100 ft) + (0.60 * 29.9 trees/l00 ft = 36.1 trees/100 A

C12: 1) As noted in T20, this requirement would add 13 ft onto the width of a Class I buffer. However, from Figure 4, it is apparent ‘that a change in width from 170 ft to 183 ft has no effect on LWD levels because essentially no LWD recruits from distances greater than 150-170 ft. Thus, this requirement is not believed to have any effect on LWD recruitment into Class I streams.

C13 : 1) As noted in T21, this requirement would add 10 ft onto the width of a Class II buffer. From Figure 4, a change in buffer width from 130 ft to 140 ft could be expected to change LWD recruitment but the amount is too small to be measured. Thus, this requirement is not believed to have any effect on LWD recruitment into Class II streams.

C 14: 1) As noted in T22, there are several difficulties in estimating the benefit of leaving no cut buffers for channel migration. For LWD, the benefit would only occur for those stream reaches &here enough channel migration occurs to significantly reduce the size of the riparian buffer, especially the no cut portion, over the life of the HCP.

2) As in T22, R2 assumed that 26.6 miles of stream would be protected by this requirement. Using the most conservative assumptions, which are that all 26.6 miles of streams would migrate completely out of their 100-170 ft buffers, and that the area outside of those buffers had recently been clearcut, then the channel migration zones would maintain uncut buffer levels of LWD on 2.7 percent of all streams. Thus, LWD levels would equal:

(.973 * 34 trees/100 ft) * (.027 * 54.9 trees/100 ft)

= (33.1 trees/100 ft) + (1.5 trees/100 ft) = 34.6 trees/100 ft.

Where 34 trees/100 ft= the average LWD recruitment of Class I and Class II streams if all of PL's proposals are implemented
34.6 trees/100 ft= the average LWD recruitment of Class I and Class II streams if all of PL's proposals are implemented and channel migration zones are instituted

Note-we used improvements over canopy levels proposed by PL, rather than those proposed in each of NMFS three options, for simplicity. However, this is conservative in that it exaggerates the benefit of NMFS' channel migration zones.

3) Thus the benefit of channel migrationzones can be estimated as (1.5/33.1) * 100 = 4.5 percent. Thus, for Class I streams LWD recruitment can be estimated as 45.9 * 1.045 = 48 trees/100 ft, and for Class II streams as 36.1 * 1.045 = 37.7 trees/100 ft.

C 15: 1) From methods in C10, the expected increase in LWD recruitment from extending the late seral buffer from 100 to 170 ft can be calculated as:

[(124 trees / 273 trees) * (1 - .97) * 54.9 trees/100 ft] = 0.75 trees/100 ft

2) However, this increase in buffer will only be applied to 50 percent of all Class II streams (PL estimate), so the composite buffer level can be calculated as:

(.50 * 31.8 trees/100 ft) * (.50 * 32.6 trees/l00 ft) = 32.2 trees/l00 ft.

C16: 1) From methods in C1 1, the expected LWD potential for Class I streams is 45.9 trees/l00 ft.

2) Under NMFS Option 2, approximately 40 percent of the Class II streams have "no cut" buffers and 60 percent do not. In addition, 50 percent of the streams have 170 ft buffers and 50 percent do not, So there are four possible treatments: 30 ft no cut plus 100 ft buffer, 30 ft no cut plus 170 ft, 100 ft late seral buffer, and 170 ft late seral buffer. For the group with a 30 ft no cut buffer and 100 ft wide buffer:

[(151.7 trees/273 trees) * (.97-.63) * 54.9 trees/l00 ft = 10.4 trees/l00 ft

And the benefit from the 30 ft no cut buffer is 34.6 trees/100 ft. So a total of 45 trees/100 ft are expected for this group.

3) Recruitment for a 170 ft wide buffer with a 30 ft no cut buffer with a is the same as calculated in 1 above = 45.9 trees/100 ft.

4) For Class IIs containing a 170 ft wide buffer with 50 year rotation, late seral stands, LWD recruitment is:

[(151.7 trees / 273 trees) * (1) * 54.9 trees/l00 ft] = 30.5 trees/l00 ft

5) For Class IIs containing a 100 ft wide buffer with 50 year rotation, late seral stands, LWD recruitment is:

[(151.7 trees / 273 trees) * (.97) * 54.9 trees/l00 ft] = 29.6 trees/100 ft

6) So average LWD recruitment for all Class II streams is:

(.20 * 45 trees/100 ft) +(.20 * 45.9 trees/l00 ft) + (0.30 * 30.5 trees/100 ft) + (0.30 * 29.6 trees/l00 ft)= 36.2 trees/100 ft

C 17: 1) Using methods outlined in Cl4 the benefit of channel migration zones can be estimated as (1.5/33.1) * 100 = 4.5 percent. Thus, for Class I streams LWD recruitment can be estimated as 45.9 * 1.045 = 48 trees/100 ft, and for Class II streams as 36.2 * 1.045 = 37.8 trees/100 ft.

Cl 8: 1) From C9, item 3, extension of the 30 ft no cut buffer from 40 percent to 100 percent of all Class II streams would increase LWD recruitment to 43.l trees/l00 ft.

C19: l) Using methods outlined in Cl1, LWD recruitment potential is increased to 45.9 trees/l00 ft.

2) Using methods outlined in C11, the potential LWD recruitment from a 50 year rotation, late seral buffer extending from 30 to 100 feet is:

[(151.7 trees / 273 trees) * (.97 - .63) * 54.9 trees/100 ft] = 10.4 trees/100 ft

And the benefit from the 30 ft no cut buffer is 34.6 trees/l00 ft. So a total of 45 trees/100 ft are expected to recruit along Class II streams.

C20: 1) Using methods outlined in Cl4 the benefit of channel migration zones can be estimated as (1.5/33.1) * 100 = 4.5 percent. Thus, for Class I streams LWD recruitment can be estimated as 45.9 * 1.045 = 48 trees/100 ft, and for Class II streams as 45 * 1.045 = 47 trees/l00 ft.

Evaluation of Reduction in Sediment Delivery to Streams

S 1: 1) As is made evident below, R2 was unable to quantify the benefits of PL and NMFS' proposals in preventing sediment delivery to streams to nearly the same extent or certainty as for large woody debris or canopy/temperature control. There are several reasons for this:

- Sediment production is inherently more complex with at least five discrete sources including: hillslope surface erosion, hillslope mass wasting, road surface erosion, road mass wasting, and streambank erosion/sloughing.

- Both NMFS and PL's proposals contain two distinct types of benefits with respect to reducing sediment delivery to streams: reduced sediment production, and changes in riparian management that would improve removal of the sediment that is still produced before it reaches streams. R2 had problems estimating each of these benefits.

- The scientific 'state of the art" for management effects on sediment loading, and particularly the benefit of different riparian prescriptions, is much more limited than it is for large woody debris or canopy/temperature.

- A key piece of data, a sediment budget for some or all of PL's lands, has not been developed.

2) Fortunately, R2's analysis was assisted by several factors. First, numerous literature studies have documented that roads are the dominant, management related sediment source (see review below). Thus, we were able to focus almost exclusively on this source without instituting a large bias in our projected benefits. Second, the sediment source control measures proposed by PL and NMFS are virtually the same, and with respect to the most important sediment source control measure, road storm proofing, are exactly the same except for the rate of implementation. Thus, any assumptions or procedures used to assess the benefits of sediment source controls, even if wrong, affect the two proposals equally. Third, as discussed below, the literature indicates that sediment filtration by riparian buffers is fairly straightforward. Thus our analysis of the differential benefits of the various riparian treatments was similarly simplified. Finally, where additional ambiguity about potential impacts or benefits was present, it was always clear how to make an assumption or approach conservative, that is, favoring NMFS' proposals.

3) Despite the favorable factors discussed in item 2 above, it is important to recognize that R2's assessment of sediment benefits used a scoring "system** that involved significant professional judgment to develop. We recognize that other reviewers could have developed a different system. The primary value of our analysis then is likely not in the absolute values obtained, but in the differential benefits assigned to each proposal.

S2: 1) As noted above, roads and harvest areas can both lead to sediment delivery to streams. However, numerous studies have documented that most mass soil movement and surface erosion in forested systems is associated with logging roads. For example, Furniss et al. (1992) report that impacts to streams and fisheries can be 1-2 orders of magnitude higher from the construction and maintenance of roads than any other forest land management activity. Similarly, comparisons of mass soil movements with various land use activities have shown that mass soil movements are 30 to more than 300 times more likely to be associated with forest roads than any other disturbance (Sidle et al. 1985). Sediment budgets by Cederholm et al. (1981), and Best et al. for forested watersheds similar to those owned by PL similarly documented the important role of roads in the total sediment contribution to streams. Thus, success in reducing sediment delivery from roads till result in a significant reduction in total sediment delivery from all sources.

2) PL's "storm proofing" of roads, using methods developed by Pacific Watershed Associates, is an attempt to reduce sediment production from roads to the maximum extent possible. NMFS and the other agencies support the use of the storm-proofing process to reduce sediment delivery to streams. Thus, proposals by PL and NMFS don't differ in regards to how roads should be improved, but rather on the rate at which PL's road mileage will be upgraded.

S3: Ideally, to assess the benefits of PL and NMFS' storm proofing proposals a quantitative analysis would be conducted to determine: a) current rates of sediment production from PL's roads, and b) how changes in sediment production from roads affect total sediment delivery to streams. However, this type of analysis would require a sediment "budget" for some or all of PL's lands, something that is not currently available. Data are available (collected by PL and Pacific Watershed Associates) to quantify the amount of sediment that is kept from entering streams because of stormproofing activities.

S4: 1) In the absence of a sediment budget, R2 used methods in the Washington State *Standard Methodology for Conducting Watershed Analysis* (Washington DNR 1996) to calculate an approximate sediment production rate for PL's roads. Deriving sediment production values from this source has many problems (e.g., not developed for Northern California, estimates are for surface erosion soil losses; etc.), but it still provides at least a heuristic value that can be compared to the known sediment savings from storm proofing. Importantly, any bias from using this source would affect the benefit of both PL and NMFS' proposals equally. (Note, R2 reviewed and considered using the analysis of road produced sediment by Cederholm et al. 1981. Although this study was not used *to* estimate sediment production on PL's lands Cederholm et al. found an average sediment production rate of 36 tons/acre road related disturbance/year, very similar to the rate calculated below using the DNR Methodology).

2) From the DNR manual, high to moderate road prism erosion rates were used to calculate a range of possible sediment production values. The Basic Erosion Rates presented in the DNR manual are for "New" (0-2 yrs) and "Old" (>2 yrs) roads and reflect the tendency for recently constructed road surfaces to "armor," as the finer particles are washed from the surface. It was assumed that most of PL's road system is older than two years, so erosion rates for roads >2 years were used. No

discounting of erosion rates was made for surfacing material, traffic use level, traffic type, or-cut and fill slope ground cover making the resulting estimates very conservative.

3) Calculated estimates of sediment production from the DNR manual ranged from 30-60 tons/acre of road surface/year. Assuming that the HCP will be in effect for 60 years, these erosion rates are equivalent to 1,800-3,600 tons of sediment produced per acre of land disturbed by roads over the life of the HCP.

4) PL has quantified the benefits of road storm proofing for work completed in the Eddysville Planning Watershed. Their estimate is that 4000 yards of sediment were prevented from entering streams for each mile of road storm proofed. This is probably a high value because the roads in the Eddysville unit were near streams and had many poor stream crossings. Roads higher up the slope or with better crossing would likely have a lower estimate of sediment saved. If 4000 yds/mile is an overestimate, again it should affect the assessment of benefits of PL and NMFS' proposals equally.

5) Assuming that the average width of ground disturbance for PL's roads is 50 ft, then PL's estimate of sediment saved can be converted to tons/acre road surface as follows:

50 ft * 5,280 ft/mile = 264,000 ft^2 of exposed mineral surface per mile of road
264,000 ft^2 / (43,560 ft^2/acre) = 6.1 acres
Therefore, 1 mile of road = approximately 6 acres of disturbed area
0.74 yards of dry gravel has an approximate weight of 1 ton
4,000 yards / 0.74 = 5,405 tons
5,405 Tons / 6 acres = 900 tons per acre

6) Thus, for every mile of road that PL storm proofs, sediment production is reduced by about 900 tons/acre of disturbed area.

S5: 1) Given results in S3, it is possible to evaluate the relative benefits of PL and NMFS' proposals.

2) As outlined in PL's draft HCP, a total of 1,520 miles of roads are present or proposed for the ownership. From S3, item 5 above, each road mile is estimated to involve 6 acres of disturbed soil, for a total of 9,120 acres. Thus for the life of the HCP, total sediment production from PL's roads can be conservatively estimated as (9,120 * 1,800 yards) = 16,416,000 yards or (9,120 * 3,600 yards) = 32,832,000 yards if no storm proofing is conducted. These are the baseline values for sediment production.

3) Both NMFS and PL have proposed to storm proof all roads on PL's ownership, thus the total benefit of each proposal is the same:

((900 tons saved/acre storm proofed) * (9,120 acres))/((16,416,000 or 32,832,000) * 100)

= 25 to 50 percent of all sediment that would otherwise be produced. The higher value of 50 percent was assumed equal to the total benefit accorded to each proposal.

4) NMFS and PL's proposals do differ in the implementation schedule for road storm proofing. PL has proposed to storm proof 500 miles of road in decade 1,500 miles in decade 2, and 520 miles in decade 3. NMFS' proposal is estimated to result in the storm proofing of 636.4 miles of road in decade 1,517.4 miles in decade 2, and 366.2 miles in decade 3. Thus the two proposals can be expected to result in some difference in total sediment saved over the first three decades of the HCP, but would be equivalent after that.

6) Using PL's proposal as an example, sediment saved in decade 1 can be estimated as:

(500 road miles * 6 acres/mile * 900 tons saved/acre) = 2,700,000 tons

7) If this analysis is done for both proposals the results are that NMFS will save 3,348,000 tons in decade 1, versus PL's 2,700,000 (a 27 percent increase), sediment saved in decade 2 is nearly identical at 2.7 (PL) to 2.71 million (NMFS) yards (a 3 percent difference), and in decade 3 PL will save 2.79 million yards compared to NMFS 2 million (a 42 percent difference).

8) The incremental benefit of NMFS proposal, then, is the benefit of preventing 27 percent more sediment from reaching the stream in decade 1 than under PL's proposal. R2 is unaware of any way to quantify the benefit of this difference to aquatic resources. On one extreme this improvement might not result in any incremental benefit, and on another could result in a 27 percent benefit. For want of a better approach, R2 "split" the difference, that is (0 percent + 27 percent)/2 = 13.5 percent.

9) Thus, from item 3 above, the total benefit of storm proofing under either proposal is 50 percent, and the additional incremental benefit of NMFS accelerated road storm proofing program is 13.5 percent for a total of 63.5 percent.

S6: 1) In addition to the benefits of road storm proofing, both PL and NMFS' proposals contain various approaches to protection of vegetated buffers along streams. These buffers could provide several sediment related benefits including: filtering of sediment from runoff or dry ravel before it reaches a stream; limiting the runout of mass soil movements so that some or all sediment is prevented from delivery; and increased bank and near-shore stability that would both prevent localized sites of sediment entry and resist channel changes expected with high sediment loading.

2) To assess the effectiveness of different riparian prescriptions, R2 undertook a review of the scientific literature examining how vegetated buffers influence the removal of sediment in runoff. This review indicated that: 1) sediment removal is influenced by slope, particle size, and most importantly, the concentration of runoff, 2) virtually no study of how buffer width affects the interception of mass soil movements has been conducted; and 3) data to quantify the benefits of different riparian prescriptions on bank stability and localized erosion were also limited.

3) What has been clearly demonstrated in the literature is that a vegetated buffer is capable of removing most or all sediment in runoff as long as that runoff is not channelized. Figure 5 contains results from R2's literature review. It shows that a buffer as little as 35 ft in width can completely remove sediment, and prevent it from entering a stream. Overall, no incremental benefit of a buffer greater than 100 ft. is evident (although individual studies have noted benefits beyond 100 ft, especially in buffers with low vegetation density) In fact, the worst sediment filtration observed occurred with the widest buffer examined, a consequence of the channelized flow examined in that study. Another way to summarize the results of the studies we examined is this: sediment that enters the riparian zone as dry ravel, sheet flow, or in small "rivulets" is quickly filtered out, but sediment that enters in channelized flow is transported to the stream almost regardless of buffer width.

4) Although the ability of vegetated buffers to remove sediment from channelized flow is limited, many authors have nonetheless concluded that buffers of 100 ft or more are protective of streams. For example, Johnson and Ryba (1992), in their review of literature on vegetation buffers, report that the majority of researchers recommended a buffer of 100 ft or greater as a "conservative" protection for streams. Similarly, Lynch and Corbett (1985) state buffer ". . .strips should be at least 30 m wide on each side of the stream channel". Erman et al. (1977) reported that logged streams with buffer strips of 100 ft or more generally had invertebrate populations that were indistinguishable from those in unmanaged systems. Moring (1982) found no statistical difference in salmon egg survival or emergence between an unlogged drainage basin, and in a stream basin subject to clearcut harvesting but with retention of a 100 ft buffer strip. Haupt and Kidd (1965) state ". . . the 10 foot minimum width of buffer strip was a fair margin of safety but that a wider minimum strip, perhaps 30 feet across would have been more desirable". Although Trimble and Sartz (1957) recommended buffer widths that varied with slope (i.e., 15-45 meters> their results show that a 100 ft buffer is sufficient to protect most streams from road related sediment. Finally, Peterjohn and Correll (1984) found "[m]ost of the total changes in concentration (mean annual total particulate runoff) occurred within the first 19m of riparian habitat."

5) Based on the results from Figure 5, and the literature we reviewed, R2 concluded that any-proposal by either NMFS or PL that resulted in an extension of buffers past 100 ft had only a small incremental benefit for sediment filtration. From Figure 5, a buffer of 75 ft was assumed to be 85 percent effective in sediment filtration,

6) Existing forest practice rules, the proposed road storm proofing, and PL's increasing use of cable yarding systems should all help to reduce channelization of sediment carrying runoff. However, to be conservative, R2 assumed that only 50 percent of all sediment entering the riparian zone is capable of being filtered out.

S7: 1) Bank stabilization is another sediment related benefit of riparian buffers. From FEMAT (1993), trees within (0.4 * site potential tree height), or about 68 ft. for PL's land, provide virtually all bank stability (although see R2's Literature Review of Riparian Management Zones for a discussion of possible problems with this analysis). Thus, an unmanaged buffer 75 ft or greater should provide maximum possible benefits for bank stability. All proposals by PL and NMFS call for buffers of 75 ft or more, so no incremental benefit for buffer width would accrue to either proposal.

2) Based on Best et al. (1995), it appears that bank erosion/sloughing can account for up to 40 percent of all sediment delivery to streams in PL's region. R2 assumed that 25 percent of that, or approximately IO percent of the total sediment budget, is due to management related actions in the riparian zone. If R2 had assumed that a greater proportion of all sediment could be controlled by limiting management activities in the riparian zone, the effect would have been to significantly increase the expected benefit of PL's 30 ft no cut zone along Class I streams, and conversion of stands from current rules to late seral stands along both Class I and Class II streams. NMFS' proposals, by contrast, would have been accorded less benefit because many of this agency's prescriptions affect conditions beyond the first 75 ft of buffer that is responsible for bank stability. (note, however, that NMFS' proposal for a 30 ft no cut buffer along Class II streams would have high benefit). Thus, R2 tried to take a conservative approach that limited the expected benefit of PL's proposals.

3) Thus, R2 assumed that 10 percent of all sediment entering the stream comes from bank and nearstream erosion and sloughing that could be prevented through changes in management. A benefit of 10 percent was assigned to a 75 ft wide buffer containing unmanaged stands (i.e., all sediment that could be prevented for entering is). The benefit of other stand conditions was taken as a simple ratio:

(treatment tree density)/(unmanaged tree density) * 10

S8: 1) R2 assumed that pre-1973, no benefits for sediment removal or bank stabilization were provided.

S9: 1) From S4, item 3, PL' road storm proofing is expected to reduce sediment inputs by 50 percent. Thus, 50 percent of all road related sediment will still be delivered to the riparian zone.

2) From S6, item 6, R2 conservatively assumed that only 50 percent of the sediment entering the riparian zone can be removed. Thus, 50 percent of 50 percent is 25 percent, that is, at best only 25 percent of all road related sediment can be removed by riparian buffers.

3) A 100 ft wide buffer provides 100 percent of the benefit expected for sediment filtration (i.e., 25 percent).

4) Bank stability/erosion benefits under current rules would be much less than the maximum of 10 percent discussed in S7, item 3. From Table 1, tree stands along Class I streams given current rules contain 98 trees acre, and from Table 2, unmanaged stands would be expected to develop 273 trees/acre. Thus, current rules would provide only (98 / 273) * 10 = 3.6 percent of the benefit expected under unmanaged conditions.

5) Total sediment benefit of current rules for Class I streams is therefore 25 percent + 3.6 percent = 28.6 percent.

S10: I) From S6, item 5, a 75 ft wide buffer provides 85 percent of the benefit expected for sediment filtration or .85 * 25 percent = 21.2 percent.. From Table 4, tree stands along Class II streams given current rules contain 67 trees acre, and from Table 2, unmanaged stands would be expected to develop 273 trees/acre. Thus, current rules would provide only (67 / 273) * 10 = 2.45 percent of the benefit expected under unmanaged conditions. A total functional value of 23.7 percent was therefore calculated.

S 11: 1) The benefit of a no cut buffer is limited to an increase in bank stability. Assuming only the first 75 ft of buffer contribute to bank stability then average tree density in this treatment is:

((30 ft/75 ft) * 273 trees/acre) + ((45 ft/75 ft) * 98 trees/acre) = 168 trees/acre

2) SO the bank stability score is 168/273 * 10 = 6.2 percent, for a total score of 25 percent plus 6.2 percent or 3 1.2 percent.

S12: 1)"Upgrading" stands to late seral status from 30-100 ft would have some benefit for bank stability. From Table 3, PL's late seral prescription is expected to result in 124 trees/acre. From Sl1, item 1, average tree density for the first 75 ft of buffer would therefore equal:

((30 ft/75 ft) * 273 trees/acre) + ((45 ft/75) * 124 trees/acre) = 183.6 trees/acre

2) So the bank stability score is 183.6/273 * 10 = 6.7 percent, for a total score of 25 percent plus 6.7 percent or 31.7 percent.

S13: 1) From Figure 5, the additional buffer width would not affect sediment filtration, and given that the increase in width occurs beyond the 75 ft of buffer that affects bank stability, no benefit on stability is expected either. Intuitively, however, increasing buffer width from 100 to 170 ft should have some benefit. R2 therefore assigned a benefit to this measure equal to 5 percent, for a total estimate of sediment saved of 36.7 percent,

S14: 1) Upgrading the stand density to late seral conditions should increase bank stability: A score of 124/273 * 10 = 4.5 percent is expected. Thus, the total sediment saved should be 21.2 percent (from S10) plus 4.5 percent = 25.2 percent.

S15: 1) Increase in buffer to 100 ft provides the full sediment filtration benefit of 25 percent but would not provide any additional bank stability value. Thus, as in S14, a bank/channel stability score of 4.5 percent was chosen for a total of 29.2 percent.

S16: 1) From S5, item 3, PL's storm proofing is e&mated to reduce road related sediment production over the life of the HCP by 50 percent. This benefit is independent of any further reductions in sediment associated with the various riparian treatments. That is, a reduction in sediment of 50 percent is equivalent to a benefit of SO percent. Thus, for Class I streams, the cumulative benefit, that is the total percentage of all road and streambank related sediment that would be prevented from entering streams is 36.7 percent plus 50 percent = 86.7 percent. For Class II streams the cumulative benefit is 29.2 percent plus 50 percent = 79.2 percent.

2) All of NMFS's proposals evaluated in the remaining footnote descriptions in this document, except for road storm proofing, involve incremental benefits in the riparian filtration/bank stability reductions in sediment delivery to streams. In each of these footnotes R2 has calculated the total benefit expected, then added this value to the 50 percent expected from PL's storm proofing program, to arrive at the cumulative percentage of all sediment saved.

S17: 1) The benefit of a no cut buffer is limited to an increase in bank stability. Assuming only the first 75 ft of buffer contribute to bank stability then average tree density in this treatment is :

((30 ft/75 ft) * 273 trees/acre) + ((45 ft/75 ft) * 124 trees/acre) = 183.6 trees/acre

2) So the bank stability score is 183.6/273 * 10 = 6.7 percent, for a total score of 25 percent plus 6.7 percent or 31.7 percent.

3) However this benefit is limited to 40 percent of all stream miles, so the average score for all Class II streams would be:

(.4 * 31.7 percent) + (.6 * 29.2 percent) = 30.2 percent.

4) Addition of the 50 percent benefit for PL's storm proofing brings the total to 80.2

S 18: 1) From S13, no benefit to bank stability or sediment filtration is expected. However, as in S13, an increase in percent sediment removed was assigned because, intuitively, increasing buffer width must have some benefit. An improvement of 2.5 percent was assigned, or half the improvement assigned to the increase in buffer width from 100 to 170 ft;

S 19: 1) As discussed in C11, this requirement is estimated to increase tree density to 151.7 trees/acre. This could be used to calculate a slightly higher bank stability value, which, in turn, would lead to slightly higher percentage values for Class I and Class II streams. However, intuitively, the benefit of increasing tree density by 22 percent in all buffer areas (except the no cut buffers) should exceed a fraction of a percent. Thus R2 assigned a value of 2.5 percent more sediment saved if this measure was implemented. This raises total percent sediment saved from delivery to Class I streams of 36.7 percent (from S 13) + 2.5 percent + 50 percent (from PL storm proofing)= 89.2 percent. It raises total percent sediment saved from delivery to Class II streams to 82.7 percent + 2.5 percent = 85.2 percent.

S20: 1) From C12, this mitigation is expected to increase the width of a Class I buffer by 13 ft, from 170-183 ft. From Figure 5, no improvement in sediment filtration is expected, and because the increase is outside of the first 75 ft of stream buffer, no benefit to stream stability is expected either. Unlike earlier proposals that increased buffer width from 100 to 130 ft, or 100 to 170 ft., intuitively an increase of 13 ft from 170-183 would not be expected to have any real benefit for sediment filtration. Thus, no incremental benefit was assigned to this proposal.

S21: 1) From C13, this mitigation is expected to increase the width of a Class II buffer by 8 ft. From Figure 5, no improvement in sediment filtration is expected, and because the increase is outside of the first 75 ft of stream buffer, no benefit to stream stability is expected either. Unlike earlier proposals *that* increased buffer width from 100 to 130 ft, or 100 to 170 ft, intuitively an increase of 8 ft from 100-108 ft or 130-138 ft would not be expected to have any real benefit for sediment filtration. Thus, no incremental benefit was assigned to this proposal.

S22: 1) As discussed in C14, analysis of the channel migration zones involves considerable uncertainty. This uncertainty, combined with the uncertainty of the current analysis for sediment, prevented R2 from conducting a quantitative analysis of the benefits of this measure. Instead, R2 assumed that, since 2.7 percent of all

PL's stream miles would be covered by channel migration zones (from C14) that the total benefit for sediment removal would equal 2.7 percent.

S23: As discussed in S5, item 8, R2 assigned an incremental benefit of 63.5 percent to NMFS' storm proofing proposal. If we subtract the 50 percent benefit from PL's storm proofmg from the current estimates for sediment, then Class I prescriptions would prevent 41.9 percent of sediment, and Class II prescriptions would prevent 37.9 percent. Adding 63.5 percent to these values gives a total value of 100 percent for both Class I and Class II streams.

S24: 1) From Figure 5, the additional buffer width would not affect sediment filtration, and given that the increase in width occurs beyond the 75 ft of buffer that affects bank stability, no benefit on stability is expected either. Intuitively, however, increasing buffer width from 100 to 170 ft should have some benefit. R2 therefore, as in S13, assigned a benefit to this measure equal to 5 percent. However, the increase in buffer width is limited to 40 percent of all Class II streams so the average benefit is .4 * 5 percent = 2 percent.

S25: 1) As discussed in S19, R2 assigned a value of 2.5 percent more sediment saved if this measure was implemented. This raises total percent sediment saved from delivery to Class I streams of 36.7 percent (from S13) + 2.5 percent + 50 percent (from PL storm proofing)= 89.2 percent. It raises total percent sediment saved from delivery to Class II streams to 82.2 percent + 2.5 percent = 84.7 percent.

S26: 1) As discussed in S20 and S21, whether the increase in buffer width is 8 ft (from 100-108 ft) or 13 ft (from 170-183 ft) no incremental benefit to sediment filtration is expected.

S27: 1) As discussed in S22, R2 assumed a benefit equal to 2.7 percent for both Class I and Class II streams.

S28: 1) As discussed in S23, the 63.5 percent benefit in reducing sedimentdelivery to streams if NMFS' storm proofing schedule is implemented increases projected sediment reductions to 100 percent for both Class I and Class II streams.

S29: 1) As discussed in S19, R2 assigned a value of 2.5 percent more sediment saved if this measure was implemented. This raises total percent sediment saved from delivery to Class I streams of 36.7 percent (from S13) + 2.5 percent + 50 percent (from PL storm proofing)= 89.2 percent. It raises total percent sediment saved from delivery to Class II streams to 81.7 percent + 2.5 percent = 84.2 percent.

Table 1: Current WLPZ Rules - Retention for Class I streams

Data From PL Stand Exams			Stand Exam Data Converted To HCP Compatible Form		
PL DBH Classes	Midpoint PL DBH lasses	#/Acre	HCP DBH Classes	Midpoint HCP DBH	# Acre in HCP Classes
7-9	8	12.82	0	0	0
9-11	10	9.49	4-8	6	6.41
11-13	12	10.77	8-12	10	21.285
13-15	14	7.18	12-16	14	17.305
15-17	16	9.48	16-20	18	16.795
17-19	18	8.21	20-24	22	14.61
19-21	20	7.69	24-28	26	8.565
21-23	22	8.21	28-32	30	5.84
23-25	24	5.11	32-36	34	3.44
25-27	26	4.15	36-40	38	1.885
27-29	28	3.72	40+	40	1.875
29-31	30	3		Total=	98.01
31-33	32	1.96			
33-35	34	1.8			
35-37	36	1.32			
37-39	38	0.93			
39-41	40	0.59			
41-43	42	0.41			
43-45	44	0.41			
45-47	46	0.2			
4749	48	0.1			
49-51	50	0.11			
51-53	52	0.16			
53-55	54	0.05			
55-57	56	0.03			
57-63	60	0.03			
63-73	64	0.03			
73-75	70	0.05			

Table 2: Vestra Modeling of PL's Limited Management Zone Buffer Stand-Conditions (at start decade 7)

DBH Class		Trees/Acre
6-11"		84.57
11-24"		153.07
24-36"		27.91
36+"		7.76
	Total=	273.31

Table 3: Stand Conditions Resulting from PL's Late Seral Prescription
(minimum post-harvest basal area of 240 square ft with size distribution requirements)

DBH Class	Required BA Retention (%)	BA (Square ft.)	Cross Sectional Area/Tree	#Trees/Acre
0	0	0	0	0
6	3	7.2	0.20	36.69
10	4	9.6	0.55	17.61
14	8	19.2	1.07	17.97
18	10	24	1.77	13.59
22	12	28.8	2.64	10.92
26	12	28.8	3.69	7.82
30	15	36	4.91	7.34
34	18	43.2	6.30	6.86
38	18	43.2	7.87	5.49
			Total =	124.27

Table 4: Current WLPZ Rules - Retention for Class II streams

Data From PL Stand Exams

PL DBH Classes	Midpoint PL DBH Classes	#/Acre
7-9	8	12.5
9-11	10	7.24
11-13	12	8.56
13-15	14	9.87
15-17	16	5.26
17-19	18	4.61
19-21	20	3.29
21-23	22	1.32
23-25	24	3.23
25-27	26	2.64
27-29	28	1.58
29-31	30	1.91
31-33	32	0.92
33-35	34	0.85
35-37	36	0.86
37-39	38	0.72
39-41	40	0.46
41-43	42	0.26
43-45	44	0.26
45-47	46	0.07
47-49	48	0.07
49-51	50	0.14
51-53	52	0
53-55	54	0.07
55-57	56	0.07
57-63	60	0.07
63-73	68	0.07
73-75	74	0.07

Stand Exam Data Converted To HCP Compatible Form

HCP DBH Classes	Midpoint HCP DBH	# Acre in HCP Classes
0	0	0
4-8	6	6.25
8-12	10	17.77
12-16	14	16.78
16-20	18	8.885
20-24	22	4.58
24-28	26	5.045
28-32	30	3.16
32-36	34	1.74
36-40	38	1.38
40+		1.38
	Total=	66.97

Figure 1: Canopy Versus Buffer Width

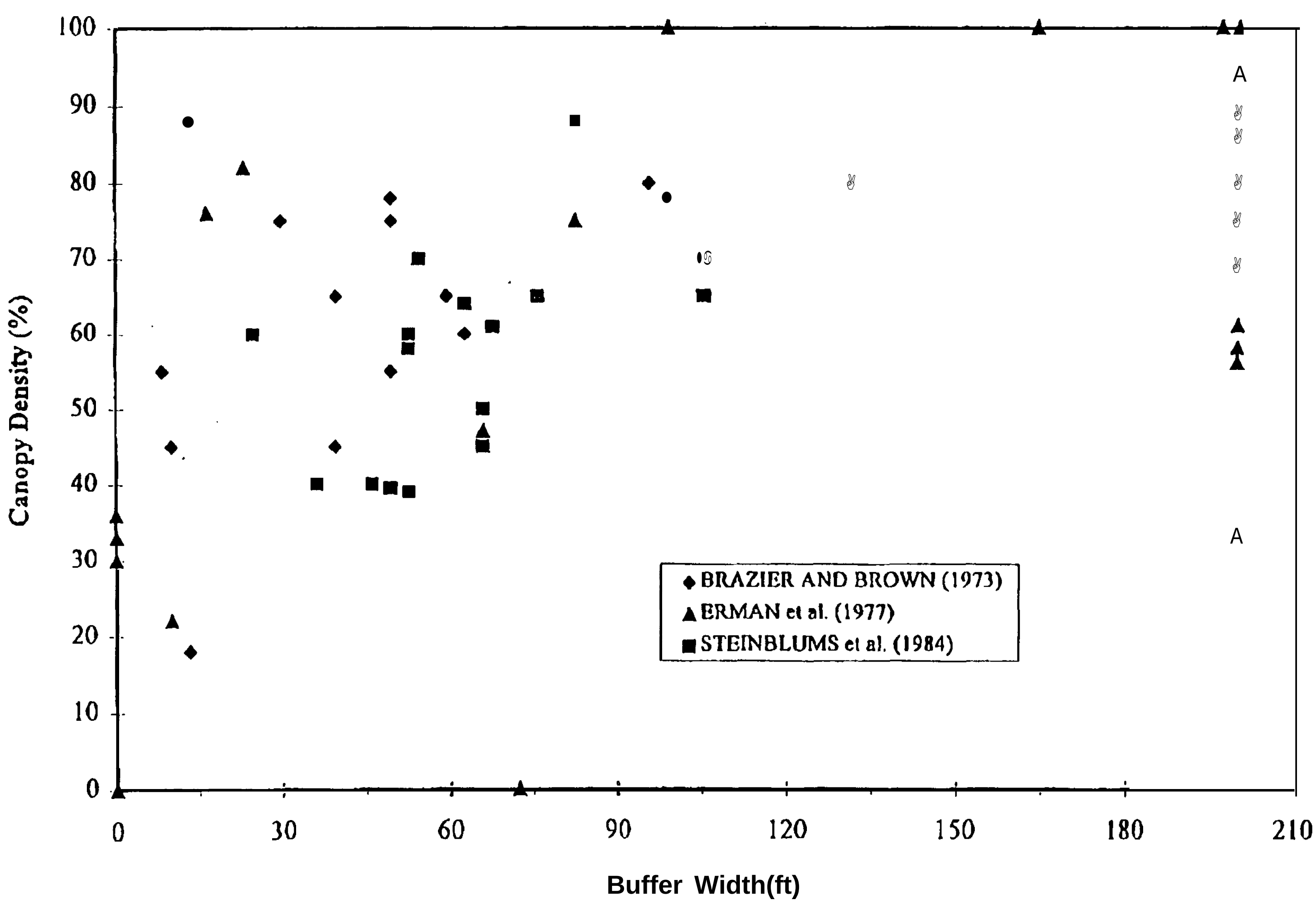


Figure 2: All Canopy Data Adjusted for Outliers

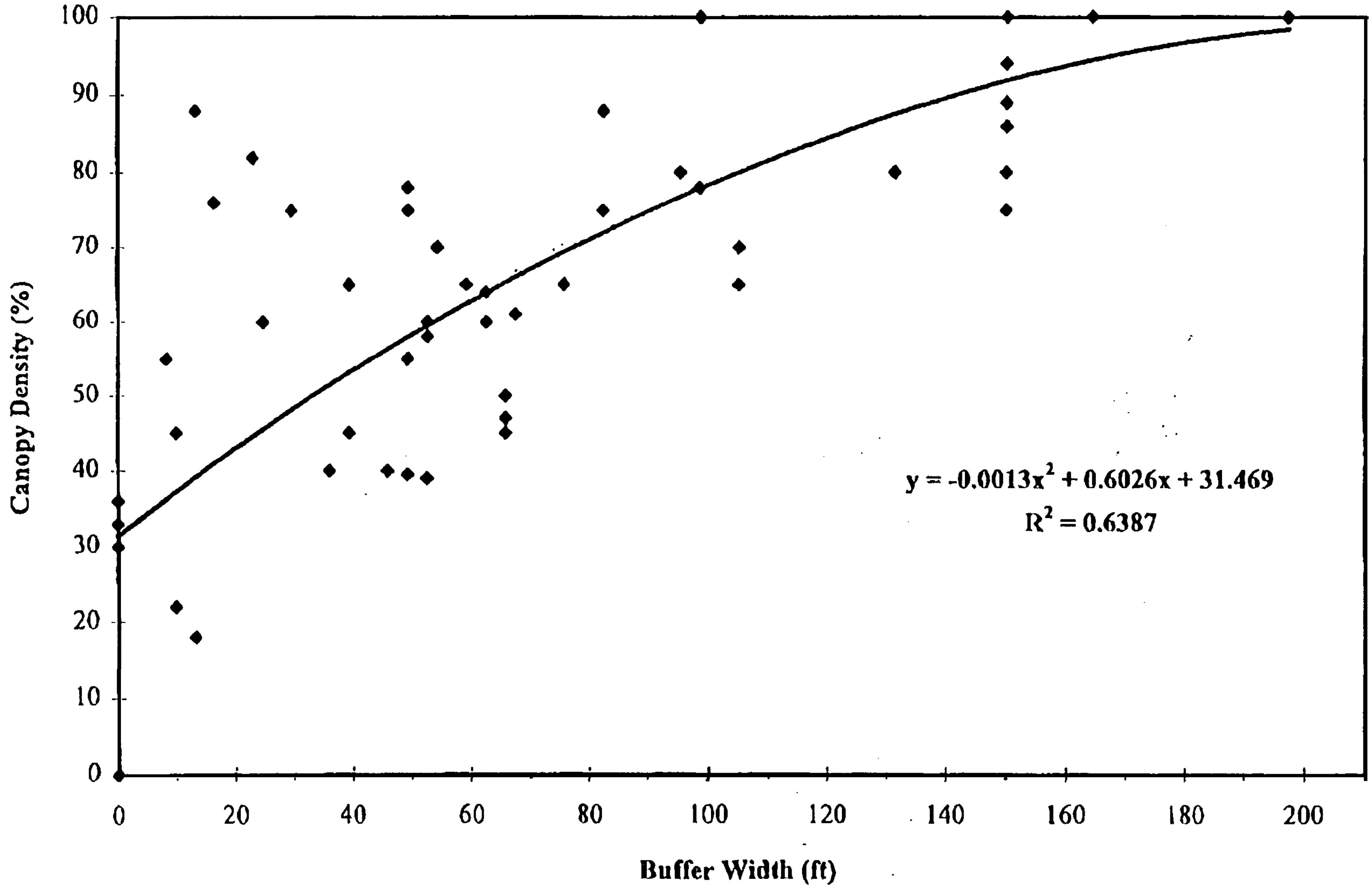


Figure 3: Tree Density Versus Percent of Canopy Density in Unmanaged Stands

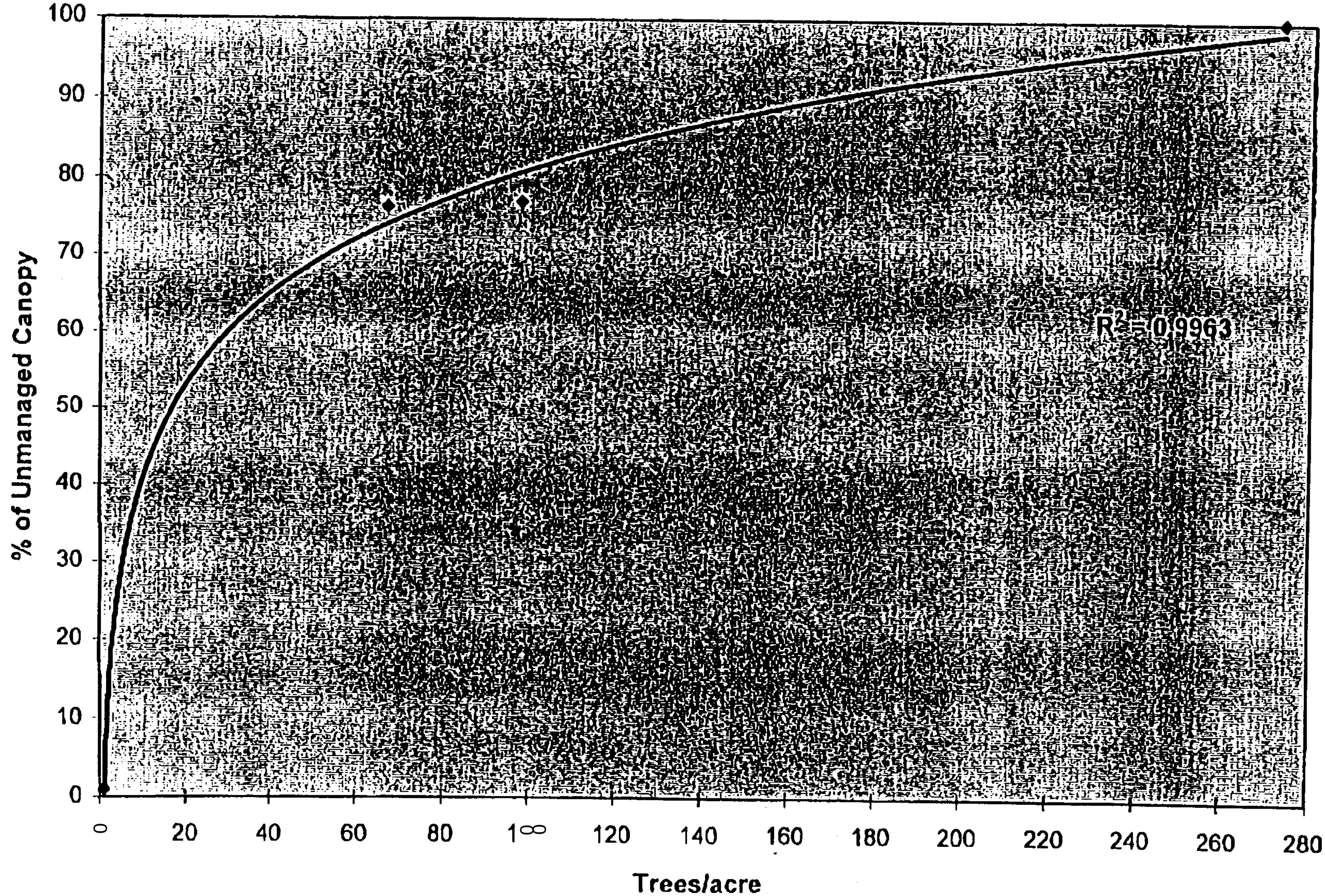


Figure 4: LWD Abundance vs Buffer Width Curve from Van Sickle and Gregory (1990)

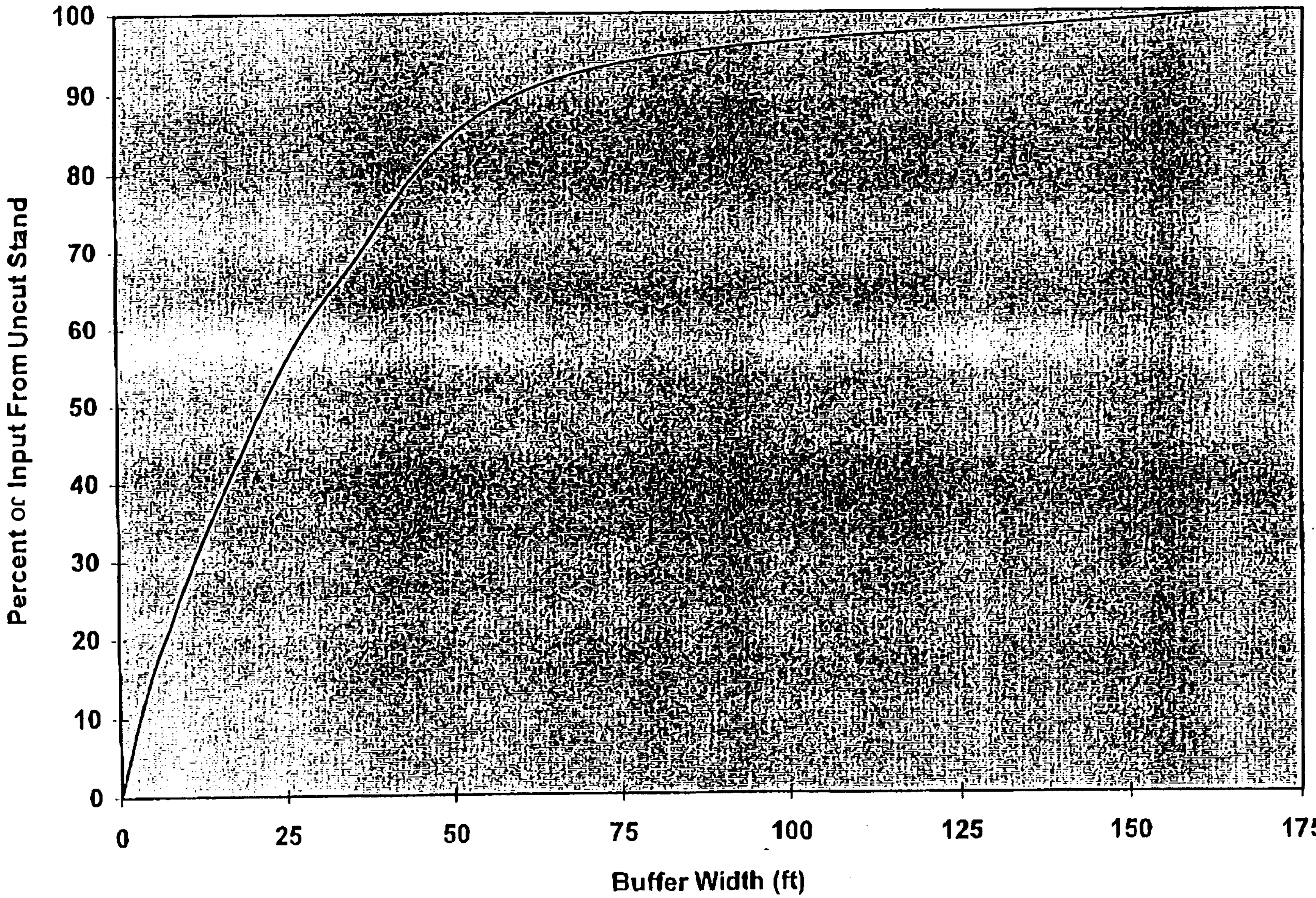
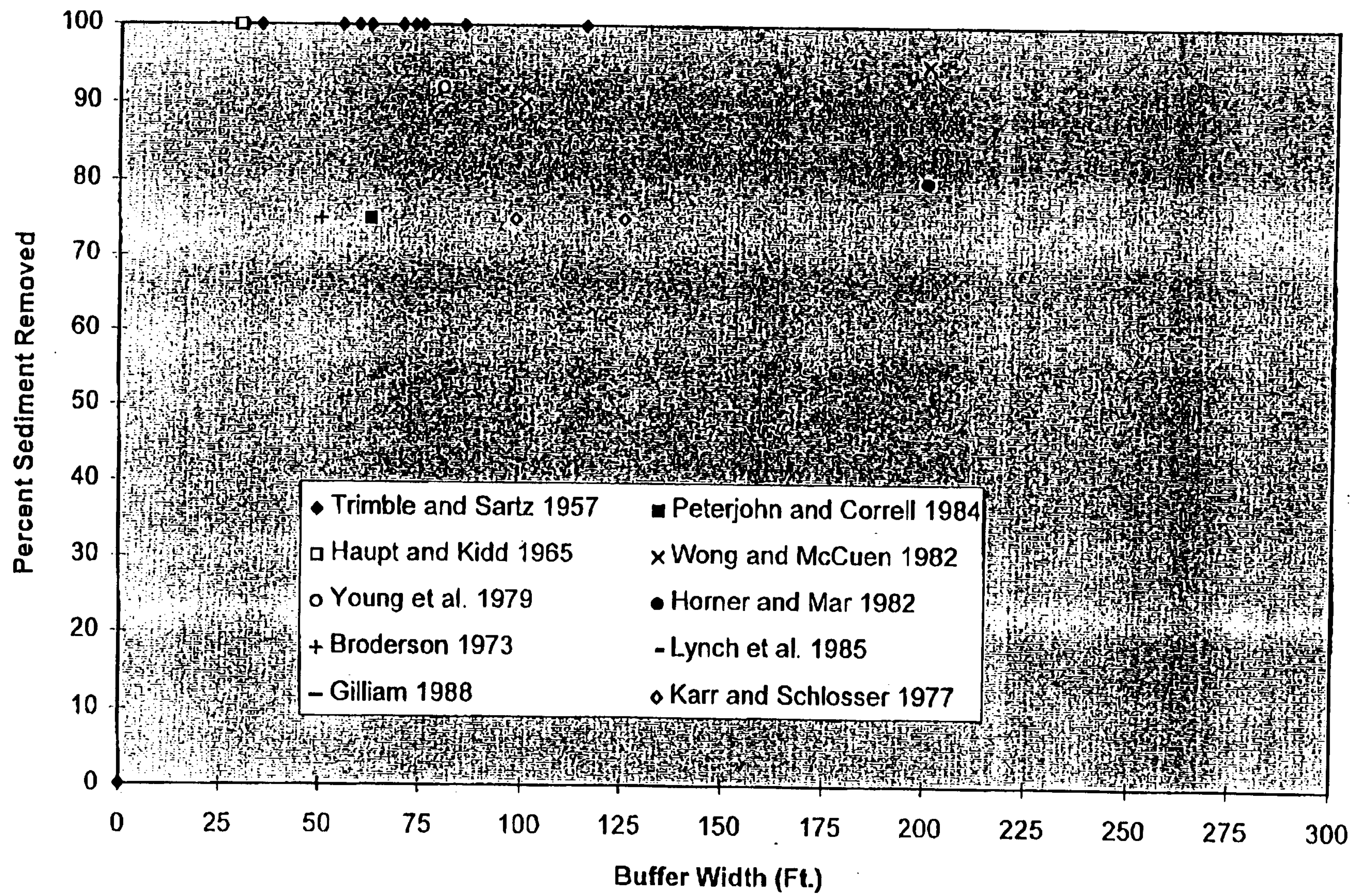


Figure 5: Buffer Effectiveness in Removing Sediment From Runoff



ATTACHMENT A

RESULTS OF FIELD AUDIT OF CANOPY RETENTION
IN CLASS I AND CLASS II WLPZs

(provided by Peter Cafferata, Calif. Dept. of Forestry)

Long-Term Monitoring Program

State Board of Forestry / California Dept. of Forestry and Fire Protection

CANOPY COVER DATA COLLECTED DURING 1996 IN HUMBOLDT AND MENDOCINO COUNTIES

The State Board of Forestry's Monitoring Study Group has developed a Long-Term Monitoring Program (LTMP) for assessing the effectiveness of the Forest Practice Rules in protecting water quaky. The initial phase of the LTMP was completed during the summer of 1996 in Mendocino and Humboldt Counties to address the increasing needs for information related to forest management and fish habitat in the range of coho salmon and other anadromous fishes. Hillslope implementation and effectiveness monitoring was completed on a stratified random sample of 25 Timber Harvesting Plans in each county. CDF contracted with the Resource Conservation Districts (RCDs) in both countries; the RCDs then hired private Registered Professional Foresters (RPFs) to conduct the hillslope monitoring. CDF provided a training program for the contractors and audited .a percentage of the THPs. Each THP had a random sample of roads, skid trails, landings, watercourse crossings, and watercourse and lake protection zones (WLPZs) evaluated.

The WLPZs selected for evaluation were located adjacent to randomly selected road segments and landings. If possible two WLPZS per THP at least 1000 feet in length were sampled, with the provision that they must be either Class I or II watercourses. Commonly it was necessary to select shorter segments, and for some plans it was not possible to evaluate two WLPZs. For Class II WLPZs, canopy cover was sampled along a transect approximately within the middle of the zone, while for Class I watercourses, canopy cover was sampled both at the mid-zone location and along the streambank. Measurements were made every 200 feet with a spherical canopy densiometer. Estimates of canopy cover were recorded for each of the cardinal directions, as 'well as for the south facing half of the densiometer grid. In the office, these, numbers were averaged for the transects as a whole and multiplied by a correction factor (1.04), as directed by the instructions accompanying the densiometer.

The data that was collected on the 50 THPs will be entered into a database developed by CDF's Fire and Resource Assessment Program (FRAP) in the winter of 1997. Prior to the entry of the data, the canopy cover measurements were averaged and entered into a spreadsheet, for rapid evaluation. Results are presented at the conclusion of the spreadsheet entries. Overall, for both counties, the Class I canopy cover averaged 80.8 percent, while the Class II cover average was 79.6 percent. Estimates of cover in Mendocino County were slightly higher than those. recorded for Humboldt County. For example, for Class I watercourses in Mendocino and Humboldt Counties, the canopy cover averaged 83.1 and 78.5 percent, respectively. Independent audits completed by CDF foresters on six THPs revealed that the contractors generally recorded higher canopy cover estimates when compared to CDF estimates. Averaged over six transects, the, contractor estimates were approximately 7.5 percent higher. Allowing for this overestimate, it can still be stated that this sample of THPs had an estimated average canopy cover of approximately 70 percent. Transects that had lower canopy cover generally had existing roads in the zones, or were influenced by landslides or excessive blowdown.

CANOPY COVER DATA COLLECTED DURING 1996 IN HUMBOLDT AND MENDOCINO COUNTIES

TRANSECT No	COUNTY	SITE	W C CLASS	HILLSLOPE POSITIO	AVE. CANOP	SOUTH FACING CANOP	COMMENTS
1	HUMBOLDT	2	I a II	MID-ZONE	64.7	62.4	
2	HUMBOLDT	2	I & II	STREAMBANK	62.1	63.6	Blowdown Influenced
3	HUMBOLDT	1	I	MID-ZONE	81.2	82.1	
4	HUMBOLDT	1	I	STREAMBANK	93.2	66.3	
5	HUMBOLDT	2	I	MID-ZONE	81.5	81.0	
6	HUMBOLDT	2	I	STREAMBANK	70.3	70.7	
7	HUMBOLDT	1	I	MID-ZONE	91.3	87.0	
8	HUMBOLDT	1	I	STREAMBANK	91.1	82.4	
9	HUMBOLDT	1	I	MID-ZONE	73.9	73.8	
10	HUMBOLDT	1	I	STREAMBANK	62.5	51.3	Landslide Influenced
11	HUMBOLDT	1	I	MID-ZONE	'c 80.4	64.2	
12	HUMBOLDT	1	I	STREAMBANK	707.0	06.8	
13	HUMBOLDT	2	I	MID-ZONE	84.6	100.0	
14	HUMBOLDT	3	I	STREAMBANK	81.6	64.5	
15	HUMBOLDT	1	I (POND)	MID-ZONE	77.7	67.4	
16	HUMBOLDT	1	II	MID-ZONE	50.5	75.6	
17	HUMBOLDT	2	II	MID-ZONE	78.6	70.3	
18	HUMBOLDT/	2	II	MID-ZONE	85.8	87.0	
19	HUMBOLDT	1	II	MID-ZONE	92.5	86.7	
20	HUMBOLDT/	2	II	MID-ZONE	84.6	85.3	
21	HUMBOLDT1	1	Ii	MID-ZONE	59.5	81.1	Blowdown Influenced
22	HUMBOLDT	2	II	MID-ZONE	75.1	67.1	Blowdown Influenced
23	HUMBOLDT	1	II	MID-ZONE	91.2	86.3	
24	HUMBOLDT	2	II	MID-ZONE	57.9	62.4	Road Influenced
25	HUMBOLDT	1	II	MID-ZONE	76.1	67.6	
26 27	HUMBOLDT	1	II	MID-ZONE	8573	93 74.9 3	
28	HUMBOLDT1	2	II	MID-ZONE	09.1	90.1	
33(	HUMBOLDT	1	II	MID-ZONE	92.7 77.7	92.6 83	
30	HUMBOLDT]	2	II	MID-ZONE			
31	HUMBOLDT	1	II	MID-ZONE	79.5	62.1	
32	HUMBOLDT	2	II	MID-ZONE	89.1	86.5	
33	HUMBOLDT	1	II	MID ZONE	80.0	71.2	
34	HUMBOLDT	2	II	MID-ZONE	90.1	07.7	
35	HUMBOLDT	1	II	MIO-ZONE	80.4	74.2	
36	HUMBOLDT	2	II	MID-ZONE	73.2	73.5	
37	HUMBOLDT	1	II	MID-ZONE	86.9	87.9	
38	HUMBOLDT]	2	II	MID-ZONE	81.6	83.2	

CANOPY COVER DATA COLLECTED DURING 1996 IN HUMBOLDT AND MENDOCINO COUNTIES

TRANSECT NO.	COUNTY	SITE	WC CLASS	HILLSLOPE POSITION	AVE. CANOPY	SOUTH FACING CANOPY	COMMENTS
39	HUMBOLDT	1	II	MID-ZONE	83.5	83.2	
40	HUMBOLDT	2	II	MID-ZONE	84.6	66.9	
41	HUMBOLDT	1	II	MID-ZONE	53.4	se.9	BLOWDOWN INFLUENCED
42	HUMBOLDT	2	II	MID-ZONE	36.2	38.5	BLOWDOWN INFLUENCED
43	HUMBOLDT	1	II	MID-ZONE	73	58.2	
44	HUMBOLDT	2	II	MID-ZONE	80	74.4	
45	HUMBOLDT	1	II	MID-ZONE	34.6	14.6	FEW TREES CUT IN WLPZ
46	HUMBOLDT	1	II	MID-ZONE	85.5	80.1	
47	HUMBOLDT	2	II	MID-ZONE	70,	62.4	
48	HUMBOLDT	1	II	MID-ZONE	93.8	97.8	
49	HUMBOLDT	1	II	MID-ZONE	94.2	95.7	
50	HUMBOLDT	1	II	MID-ZONE	45.8	31.9	
51	HUMBOLDT	1	II	MID-ZONE	89.1	84.6	
52	HUMBOLDT	2	II	MID-ZONE	-90.9	86	
53	MENDOCINO	-	-	-			NO CLASS I/II > 500 FT
54	MENDOCINO	-	-	-			NO CLASS I/II > 500 FT
55	MENDOCINO	1	I	MID-ZONE	81.8	83.5	
56	MENDOCINO	1	I	STREAMBANK	86.9	97.4	
57	MENDOCINO	2	I	MID-ZONE	88.4	82.2	
58	MENDOCINO	2	I	STREAMBANK	82.2	92.9	
59	MENDOCINO	2	I	MID-ZONE	91.3	100	
60	MENDOCINO	2	I	STREAMBANK	95.6	98.8	
61	MENDOCINO	1	I	MID-ZONE	78.3	87.7	
62	MENDOCINO	1	I	STREAMBANK	67.6	76.3	ROAD INFLUENCED
63	MENDOCINO	2	I	MID-ZONE	89.9	89.4	
64	MENDOCINO	2	I	STREAMBANK	85.1	81.5	
65	MENDOCINO	1	I	MID-ZONE	91	90.5	
66	MENDOCINO	1	I	STREAMBANK	92	81.5	
67	MENDOCINO	2	I	MID-ZONE	72.8	65.2	
68	MENDOCINO	2	I	STREAMBANK		63.4	ROAD IN WLPZ
69	MENDOCINO	2	I	MID-ZONE	83.1	71.4	
70	MENDOCINO	1	II	MID-ZONE	81.1	78.3	
71	MENDOCINO	2	II	MID-ZONE	04.7	86.3	
72	MENDOCINO	1	II	MID-ZONE	85.4	79.4	
73	MENDOCINO	2	II	MID-ZONE	96.9	9s.7	
74	MENDOCINO	1	II	MID-ZONE	86.5	82.2	
7s	MENDOCINO	2	II	MID-ZONE	90.4	99	
76	MENDOCINO	1	II	MID-ZONE	92.6	98.8	
77	MENDOCINO	2	II	MID-ZONE	77.9	87	
78	MENDOCINO	2	II	MID-ZONE	92	89	

CANOPY COVER DATA COLLECTED DURING, 1996 IN HUMOLDT AND MENDOCINO COUNTIES

RANSECT NO.	COUNTY	SITE	WC CLASS	ILLSLOPE POSITIO	AVE.CANOPY	OUTH FACING CANOP	COMMENTS
79	MENDOCINO	1	II	MID-ZONE	90.5	00.7	
80	MENDOCINO	2	II	MID-ZONE	05.5	03.9	
61	MENDOCINO	1	II	MID-ZONE	90.5	90.5	
02	MENDOCINO	1	II	MID-ZONE	90.1	09.4	
83	MENDOCINO	2	II	MID-ZONE	85.3	04.2	
04	MENDOCINO	1	II	MID-ZONE	83.7	08.1	
85	MENDOCINO	2	II	MID-ZONE	85.7	90.8	
86	MENDOCINO	1	II	MID-ZONE	77.0,		
87	MENDOCINO	1	II	MID-ZONE	75.2	77.3	
88	MENDOCINO	2	II	MID-ZONE	60.4	06.7	pen areas predate THP
09	MENDOCINO	1	II	MID-ZONE	93.5	87 4	
90	MENDOCINO	1	II	MID-ZONE	72.1	75.6	Road Influenced
91	MENOOCINO	2	II	MID-ZONE	09.7	09.0	
92	MENDOCINO	2	II	MID-ZONE	92.2	01.1	
93	MENDOCINO	1	II	MID-ZONE	86.6	86.8	
94	MENDOCINO	1	II	MID-ZONE	77.5	79.0	
95	MENDOCINO	1	II	MID-ZONE	47.5	38.8	Road Influenced
96	MENDOCINO	1	II	MID-ZONE	77.9	79.7	
97	MENDOCINO	2	II	MID-ZONE	68.3	65.5	
98	MENDOCINO	1	II	MID-ZONE	85.7	01.1	
99	MENDOCINO	2	II	MID-ZONE	04.8	73.6	
100	MENDOCINO	1	II	MID-ZONE	76.5	07.4	
101	MENDOCINO	2	II	MID-ZONE	73.1	75.2	Road in WLPZ
102	MENDOCINO	1	II	MID-ZONE	84.0	83.2	
103	MENOOCINO	2	II	MID-ZONE	51.3	70.7	

HUMBOLDT	CLASS I AVE	70.4533333
HUMBOLDT	CLASS II AVE	77.7540541
HUMBOLDT	LASS I & II AVE	77.9557692

MENDOCINO	CLASS I AVE	03.14
MENDOCINO	CLASS II AVE	81.5823529
MENDOCINO	LASS I & II AV	82.0591837

OVERALL	CLASS I AVE	00.7966667
OVERALL	CLASS II AVE	79.5673239
OVERALL	LASS I & II AVE	79.9465347

OC/981420006

CANOPY MEASUREMENTS

Audit Comparison

TRANSECT NO.	COUNTY	SITE	WC CLASS	ILLSLOPE POSITIO	VG CDF CANOP	AVG CONTRACTOR CANOPY
11	HUMBOLDT	1	I	MID-ZONE	75.7	90.4
13	HUMBOLDT	2	I	MID-ZONE	74.1	84.6
39	HUMBOLDT	1	II	MID-ZONE	65.6	83.5
82	MENDOCINO	1	II	MID-ZONE	79.6	90.1
87	MENDOCINO	1	II	MID-ZONE	84.3	75.2
99	MENDOCINO	2	II	MID-ZONE	84.8	84.8
CDF	AVG	77.350				
CONTRACTOR	AVG	84.76667				